COLUMBIA RIVER MAINSTEM STORAGE OPTIONS, WASHINGTON

OFF-CHANNEL STORAGE ASSESSMENT PRE-APPRAISAL REPORT

Prepared for

Washington State Department of Ecology

U.S. BUREAU OF RECLAMATION

by

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1.0 EXECUTIVE SUMMARY

1.1 BACKGROUND OBJECTIVES

The Columbia River provides water for a variety of uses throughout the northwest. While natural flow in the river is under increasingly heavy demand from agricultural, municipal, industrial, and power generators, the need to maintain flow for fish and wildlife, recreation and cultural resources is of growing importance. The availability of noncommittal water is seasonal, thus water storage becomes the only practical method to take advantage of any available flow. Since additional instream storage on the mainstem of the Columbia River is not considered feasible, off-channel storage becomes the only feasible option.

The intent of this study is to evaluate potential off-stream storage sites that could retain a minimum of 300,000 are-feet of Columbia River water for annual use. This is a pre-appraisal-level evaluation intended to: 1) identify potential 300,000 acre-foot storage sites within 10 miles of the mainstem of the Columbia River; 2) assess the availability of water for supplying the storage reservoir; 3) develop a preliminary inventory of site related physical, environmental and cultural characteristics for each site; 4) develop pre-appraisal-level opinions of probable capital cost of each alternative for each site identified; and 5) provide storage site evaluation criteria for use by others in analyzing and assessing the alternative sites.

1.2 INTRODUCTION

Section 2 of the report defines the background and purpose for the study, the authority for its development, the report format and a general description of the project area in Washington State that include Upper Columbia River Region, the Mid Columbia River Region and the Lower Columbia River Region. This section also covers the characteristics of each area that were investigated to determine the availability of storage and dam sites that would satisfy the objectives of the study.

1.3 NEEDS ASSESSMENT

Section 3 provides a brief description of the potential need for additional water based upon five defined uses:

- Agriculture
- Fish and Wildlife Resources
- Municipal and Industry
- Recreation
- Power Generation

This section summarizes the current and future water needs of the study area using available reports, publications, available files, and discussions with individuals knowledgeable of the subject.

1.4 ECONOMIC BENEFITS/COSTS OF PROVIDING ADDITIONAL STORAGE WATER TO SATISFY IDENTIFIED NEEDS

Section 4 provides an assessment of the potential benefits and relative costs associated with the availability of additional water storage, based upon sources of available information. The relative costs are based on order of magnitude estimates developed from very limited information. Consequently, they are not of a level of accuracy adequate for use by readers of this report as expected total project costs. More detailed estimates may vary substantially from those used for the purposes of alternative comparisons in this report. (The use of these estimated construction costs outside the context of this report will be misleading and inappropriate.)

1.5 IDENTIFIED STORAGE OPTIONS FOR OFF-CHANNEL SITES OF 300,000 ACRE-FEET OR GREATER

Section 5 provides the analysis of potential storage sites based upon the assumptions and study criteria presented. It defines our methods and approach for identifying potential storage sites and how we analyzed each option to arrive at eleven (11) candidate locations. These eleven sites are shown in Table 1-1 below and were selected from an initial list of 20 possible sites.

Table 1-1. Feasible Off-Channel Water Storage Sites

Site	**Total Storage Volume**
Ninemile Flat	1,024,000
Hawk Creek	1,550,000
Goose Lake	3,619,000
Foster Creek	1,321,000
Mission Creek	481,000
Moses Coulee	4,126,000
Sand Hollow	1,228,000
Crab Creek	2,653,000
Alder Creek	331,000
Rock Creek East	998,000
Kalama River	1,185,000

Section 5 also includes an analysis of Columbia River water seasonal availability and flows using information provided by a variety of agencies. Information on water diversion facilities (pumps, waterways, etc.) is provided as well as the physical characteristics of each dam and reservoir site selected for a more detailed evaluation. Only those sites that satisfied the target storage volume and basic physical and engineering criteria/assumption were evaluated in detail.

Each feasible site is presented in sufficient detail to assess its location, characteristics, feasibility, and general capital cost. In addition, each feasible site was evaluated in terms of its environmental and institutional characteristics and potential concerns. Table 1-2 provides a summary of that analysis.

Table 1-2. Columbia River Potential Surface Storage Sites Institutional and Environmental Issues of Concern

Site	Anadromous Fish Passage	Wetland Impacts (NWI)	Infrastructure Impacts	Land Use Impacts/Land Ownership Issues	Federal Terrestrial T&E Species Impacts[1,2]	State Terrestrial Sensitive Species Impacts[2]
Ninemile Flat	No	Yes – 326 acres	Negligible	Colville Indian Reservation, Indian Trust Assets	No	Unlikely Fisher listed (E)
Hawk Creek	No	Yes – 50 acres	Negligible	Minimal	No	Unlikely Sharp-tailed grouse listed (T)
Goose Lake	No	Yes – 382 acres	Negligible	Colville Indian Reservation, Indian Trust Assets	No	Unlikely
Foster Creek	No	No NWI recorded	Transmission lines, state highway, local roads	Some agriculture	No	Sharp-tailed grouse possible (T) Sage grouse listed (T)
Mission Creek	Yes – chinook, steelhead	Yes – 4 acres	County highway, local roads	Extensive orchards, residences, farm structures	Northern spotted owl (T) habitat, one plant species (E) possible	Northern spotted owl listed (E), Loggerhead shrike (C) possible; one plant species (E) and two plant species (T) possible
Moses Coulee	No	Yes – 4 acres	County road, local roads, abandoned RR line, abandoned historic town site	Agriculture, range land, some residences, agricultural structures	Pygmy rabbit (E) habitat; Greater sage grouse (C) habitat; Washington ground squirrel (C) habitat; three plant species (C) possible	Pygmy rabbit (E) possible; Greater sage grouse listed (T); Ferruginous hawk listed (T); one (E) plant and three (C) plant species possible
Sand Hollow	No	Yes – 69 acres	State highway, local roads, transmission line	Extensive agriculture	Washington ground squirrel (C) habitat	Unlikely Northern leopard frog listed (E); Ferruginous hawk listed (T)
Crab Creek	Yes – steelhead	Yes – 18,663 acres	County road, transmission lines, abandoned RR line	National and State Wildlife refuges, minor agriculture	Washington ground squirrel (C) habitat; three plant species (C) possible	Burrowing owl (C), loggerhead shrike (C), sage sparrow (C), sage thrasher (C), black-tailed jack rabbit (C) possible; one plant species (E) and five plant species (T) possible
Alder Creek	No	Yes – 18 acres	Alderdale Road, petroleum pipeline	None	Townsend's ground squirrel (C) habitat	Western gray squirrel (T), Burrowing owl (C), loggerhead shrike (C), black-tailed jack rabbit (C)and white-tailed jack rabbit (C) possible
Rock Creek East	Yes- chinook, steelhead	Yes – 32 acres	Boat ramp, picnic area, access road, petroleum pipeline	None	None	Western gray squirrel listed (T); Golden eagle (C), Lewis' woodpecker (C), Western toad (C) possible
Kalama River	Yes – chinook, coho, steelhead	Yes – 172 acres	Local road, transmission line	Logging	Bald eagle (T), Northern spotted owl (T) habitat	Northern spotted owl (E) possible; Bald eagle listed (T)

Notes:
1. "Habitat" indicates presence of suitable habitat based on GAP vegetation analysis; this is not federally designated "critical habitat." E = Endangered, T = Threatened, C = Candidate
2. "Possible" indicates that a species has been observed in or near the potential dam/reservoir area; "unlikely" indicates that suitable species habitat is present, but no observations have been recorded.

1.6 OPINION OF CAPITAL CONSTRUCTION COST FOR IDENTIFIED FEASIBLE OFF-CHANNEL STORAGE SITE

Section 6 presents the opinion of capital construction cost and the cost for water storage on an acre-foot basis. Table 1-3 provides a summary of that analysis.

Table 1-3. Pre-Appraisal Level Cost Estimates of Potential Columbia River Off-Channel Storage Sites*

Site	Total Storage (acre-feet)	Cost Estimate[1] ($millions)	$/AF[1] ($)	Cost Estimate[2] ($millions)	$/AF[2] ($)
Ninemile Flat	1,030,000	$1,293	$1,260	$1,455	$1,410
Hawk Creek	1,550,000	1,444	930	1,624	1050
Goose Lake	3,720,000	2,967	800	3,340	900
Foster Creek	1,340,000	2,976	2,220	3,348	2,500
Mission Creek	470,000	1,235	2,630	1,390	2,960
Moses Coulee	4,130,000	1,891	460	2,127	520
Sand Hollow	1,230,000	971	790	1092	890
Crab Creek	2,650,000	1,703	640	1,915	720
Alder Creek	330,000	491	1,490	552	1,670
Rock Creek East	1,000,000	1,195	1,200	1,345	1,350
Kalama River	1,185,000	1041	880	1172	990

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.
1 - Based on 20% of Direct Construction Costs
2 - Based on 35% of Direct Construction Costs

1.7 EVALUATION CRITERIA DEVELOPMENT FOR ADDITIONAL INVESTIGATION

Section 7 provides recommended evaluation criteria of further analysis and evaluation of off-channel storage sites. The criteria are developed for four general objectives:

- Project Completeness
- Effectiveness
- Efficiency
- Acceptability

These objectives were then further divided into specific subcriteria under each objective. The subcriteria can then be rated in terms of how successfully the objectives are satisfied for each area. The criteria are intended to be non-inclusive and we would encourage that the list of subcriteria be expanded as the future analysis progresses.

2.0 INTRODUCTION

2.1 PURPOSE

The purpose of this study is to develop a Columbia River Storage options report as part of an overall effort to identify and assess options for new water supply opportunities along the mainstem Columbia River, beginning in the fall of 2005. The options to be focused on primarily are new or enhanced storage capabilities (off-stream versus on-stream storage, pumped storage, modification of existing facilities to allow for additional storage capacity, new dam sites, etc.). In addition, a set of evaluation criteria are proposed which the State of Washington (State), the Bureau of Reclamation (Reclamation), and interested parties can use to prioritize sites for additional analysis.

2.2 BACKGROUND

The U. S Bureau of Reclamation entered into a *Memorandum of Understanding Concerning the State of Washington's Columbia River Initiative* (MOU) on December 19, 2004, with the State of Washington and the Columbia Basin irrigation entities of South Columbia Basin Irrigation District, East Columbia Basin Irrigation District, and Quincy-Columbia Basin Irrigation District. Under the MOU the parties agreed to cooperate in initiating an appraisal level assessment of the potential to store additional water from the Columbia River mainstem, including an assessment of the costs and benefits of alternative water storage sites. The scope of the pre-appraisal-level work included in this study is limited to identification of alternative storage sites and stops short of developing reliable estimates of project costs and benefits.

The pre-appraisal-level cost estimates listed for each alternative storage site in the tables of Section 5 represent one of the proposed selection criterion parameters. They were developed using an abbreviated technique to generate consistent cost estimates of each alternative. They are appropriate for making relative comparisons between individual alternatives but are neither appropriate nor accurate estimates of project development costs for use in planning or budgeting.

2.3 AUTHORITY

The authority for this study was contained in Task Order No. 03B010150A of Contract No. 03CA10150A for an ID/IQ A&E Contract for A-E services dated July 8, 2005 and signed by Mr. Joseph W. Pratt.

2.4 ABBREVIATIONS AND ACRONYMS

AF – acre-foot

ASR – aquifer storage and recovery

BiOp – Biological Opinion

BPA – Bonneville Power Administration

C - Candidate

cfs – cubic feet per second

DEM – digital elevation model

E - Endangered

Ft - feet

FCRPS – Federal Columbia River Power System

GAP - Geographic Approach to Planning

GIS – Geographic Information System

HYDROSIM - Hydrologic Simulation

IA - Irrigated Acres

KAF – thousands of acre-feet

Kw - Kilowatt

M&I – municipal and industrial

MR&I – municipal, rural and industrial

MSL - Mean Sea Level

MW – megawatt

MWh – megawatt-hour

NL - Not Listed

NMFS – National Marine Fisheries Service

NWI - National Wetland Inventory

SC - State Candidate

SE - State Endangered

ST - State Threatened

T - Threatened

USACE – United States Army Corps of Engineers

USBR – U. S. Bureau of Reclamation

USGS - United States Geological Survey

WAGAP - Washington GAP Analysis

WA DOE – Washington Department of Ecology

WHNP - Washington Natural Heritage Program

WRIA - Water Resource Inventory Area

2.5 REPORT FORMAT AND SCOPE OF STUDY

The report is prepared using Microsoft WORD for text, EXCEL for spreadsheets, and GIS maps are in ESRI's ArcGIS v.8.1.

The scope of services includes the following:

(1) Identifying the need for additional off-channel storage and/or the benefit of additional off-channel storage.

(2) Describing the primary and secondary economic (monetary and non-monetary) effects that could result from access to additional stored water.
(3) Incorporating locations identified in the past and the proponents.
(4) Identifying water availability.
(5) Identifying any opportunities for aquifer storage.
(6) Providing appraisal level estimated costs of constructing new off-channel, multipurpose storage for a range of generic facilities in $ per acre foot.
(7) Proposing a set of criteria that the State, Reclamation, and others could use to prioritize sites for additional investigations.

2.6 STUDY AREA

The Columbia River Basin is North America's fourth largest watershed, covers nearly 260,000 square miles and spans seven states and one Canadian province. The northernmost reach of the watershed is found in the high glaciers of the Canadian Rockies. From there, the main body of the Columbia River runs over a thousand miles before reaching the Pacific Ocean.

The Columbia River originates in two lakes that lie between the Continental Divide and Selkirk mountain ranges in British Columbia. It flows north for its first 200 or more miles, then it turns south and runs to the international border. Within the United States, the river flows southwest skirting one of the Columbia Plateau's massive lava flows before turning southeast and cutting a dramatic gorge in the volcanic shield to its junction with the Snake River. From its confluence with the Snake, the Columbia runs nearly due west to the Pacific Ocean.

The Columbia River Basin includes a diverse ecology that ranges from temperate rain forests to semi-arid plateaus, with precipitation levels from 110 inches to 6 inches per year. Most important, perhaps, the Columbia is a snow-charged river that seasonally fluctuates in volume. Its annual average discharge is 160 million acre-feet of water, with the highest volumes between April and September, the lowest from December to February. From its source at 2,650 feet above sea level, the river drops an average of more than 2 feet per mile, but in some sections it falls nearly 5 feet per mile (Bill Lang Professor of History Portland State University, Former Director, Center for Columbia River History: http://cbi.wsu.edu/vft/columbia/_tourlaunch1.htm).

The Columbia has ten major tributaries: the Kootenay, Okanagan, Wenatchee, Spokane, Yakima, Snake, Deschutes, Willamette, Cowlitz, and Lewis rivers. Its most important tributary, the Snake, flows across a semi-arid plain and runs through the deepest gorge in North America, Hell's Canyon -- 7,900 feet deep. The Deschutes and Willamette rivers drain basins south of the Columbia, while the Yakima, Lewis, and Cowlitz rivers drain areas on the north side of the river (Lang, 2004).

The Columbia River Basin is the most hydroelectrically developed river system in the world. More than 400 dams -- 11 run-of-the-river dams on the mainstem -- and hundreds of major and modest structures on tributaries block river flows and tap a large portion of the Columbia's generating capacity: more than 21 million kilowatts. The hydroelectric projects connect the entire region through a network of interties and relay stations into a power grid system. A treaty with Canada in 1964 and creation of the NW-SW Intertie with California made the network inter-regional and international.

The Columbia River from a standpoint of navigation may be divided into three sections; namely, the tidal or lower section extending from the mouth to a point about 140 miles from the mouth; the middle section extending from the head of tidewater to the mouth of Snake River, a distance of about 180 miles; and the upper section extending from the mouth of Snake River to the international boundary, about 424 miles (USACE, 1926).

2.6.1 Upper--Columbia River Region

As early as the 1870s, agriculture benefited from Columbia River water. By the 1920s, major irrigation projects along the Columbia and tributaries, such as the Yakima, Wenatchee and Umatilla rivers operated with the benefit of federal programs. During the 1930s and 1940s, however, the construction of the big dams, especially Grand Coulee Dam in 1941 on the upper river, greatly increased irrigated agriculture on the Columbia Plateau. In 1948, the Columbia Basin Project began transporting Columbia River water by canal to more than 600,000 acres on farms in central Washington. This project requires massive pumping stations, a labyrinth of canals, and enormous center-pivot sprinkler systems. Major irrigated crops include grain, alfalfa, ensilage crops, potatoes, sweet corn, mint, sugar beets, beans, orchard fruit, and wine grapes. Dairy farming and beef production is significant in the area.

Rock Island Dam was the first major hydropower producer on the mid-Columbia completed in 1932. Chief Joseph, completed in 1953, was the second largest Federal dam that increased irrigation storage capacity.

2.6.2 Mid-Columbia River Region

The Snake at more than 1,100 miles long is the largest of the rivers that feed into the Columbia. In fact, the streams and small rivers feeding into the Snake represent 49 percent of the Columbia River Basin watershed below the Canadian border.

2.6.3 Lower-Columbia River Region

The Columbia provides a nearly sea-level pathway through the Cascade mountain range to eastern regions of Oregon and Washington. The reach of tide extends to the western end of the Gorge, a little more than 100 miles from the Pacific Ocean. This lower river section is flat, falling less than one half-foot per mile. It includes Sauvie Island, one of the largest river islands in North America.

Because of the 40-foot-deep channel in the Lower River and slackwater lakes on the middle-river, ocean freighters can navigate up the Columbia and Willamette rivers to Portland and barges can transport goods to the interior. Towboats push the barges up through navigation locks on Bonneville, The Dalles, John Day, McNary, and four Snake River dams, carrying diesel fuel and other commodities upriver, and grain, wood chips, agricultural products, and lumber down river.

John Day Dam, a Federal dam completed in 1968, added another important increase in irrigation storage capacity.

2.7 EXISTING OFF-CHANNEL STORAGE IN THE COLUMBIA RIVER DRAINAGE

There are 61 dams on the mainstem of the Columbia River and its tributaries according to the Columbia Basin Water Management Division of the USACE. The vast majority of the over 55,000,000 acre-feet of storage in the basin is contained within the reservoirs of the mainstem and its tributaries. Of the fourteen storage dams located on the mainstem, three are in Canada (Mica, Revelstoke, and Keenlyside) and the remaining are in the United States (Grand Coulee, Chief Joseph, Wells, Rocky Reach, Rock Island, Wanapum, Priest Rapids, McNary, John Day, The Dalles and Bonneville).

Only four of the remaining 47 dams are located off-stream from a Columbia River tributary (Salmon Lake, Okanogan Irrigation District; Mill Creek, COE; Cold Springs, USBR; and Haystack, USBR/North Unit Irrigation). The maximum storage capacity of the four off-stream storage reservoirs totals approximately 75,000 acre-feet which is less than approximately 0.15 percent of the total storage in the Columbia River system.

3.0 NEEDS ASSESSMENT

3.1 BASIS AND LIMITS OF NEEDS ASSESSMENT

The Report *"Mainstream Columbia River Storage Options"* provides an assessment and inventory of potential new Columbia River water storage opportunities off the mainstream of the Columbia River. This section of the report provides a brief discussion of the need for additional storage and water along the mainstream of the river and a summary assessment of those anticipated or projected water requirements. Needs were categorized into five groups:

- Agricultural
- Fish and Wildlife (F&W)
- Municipal and Industrial (M&I)
- Recreation
- Power Production (Hydroelectric)

As a result of several recent changes in annual climatic and stream discharge patterns, the northwest has experienced nearly 10 years of drought conditions. Due to a growing number of water rights applications in Washington for a variety of uses, and technical and political concerns regarding the best way to manage the limited resources of the River for both economic development and environmental protection and enhancement, a number of plans and recommended changes to the existing allocation and distribution of water have been proposed. As the demand for both consumptive and non-consumptive use of Columbia River water increases and the supply remains static or, as in recent years, decreases, it becomes more important to understand both the needs and the best beneficial uses of the available supply in order to satisfy the economic, environment and social requirements of the region.

The area surrounding the Columbia River considered by this study for the diversion, storage, and use of surface water was limited to a 10-mile corridor on each side of the river from the Canadian border to the Pacific Ocean. The area of use was limited by both the general need in terms of the expected population and economic demand, as well as the practical geographical and physical limitations for the storing and transportation of water, and engineering feasibility and cost of large water resource projects.

Information for this review of water needs was compiled from available existing published information and through discussion with individuals with specific knowledge as to the existing and future water needs for the area. Both non-consumptive and consumptive uses were considered. Non-consumptive uses include fish and wildlife requirements, recreation, and power generation; these water uses are accomplished by using instream flows. The exception to that would be off-stream storage (off-stream dams or pump storage) that would modify the natural flow patterns and release water to the Columbia River at specific periods to provide for an engineered use (i.e., high demand electrical power requirements, M&I, fish flushing flows, etc.) from an impoundment. Consumptive uses typically require off-stream diversion for irrigation of crops, domestic water supply and industrial use. However, "consumptive use" generally does not completely consume all of the diverted water and often includes a volume of water returned to that drainage system in the form of agriculture return flow, groundwater discharge back to the river system, aquifer recharge (which may result in a net reduction in surface water pumping), municipal and industrial treated wastewater discharges and other return flows.

The four major water demands on the river are anadromous fish passage, agriculture, M&I, and power generation. Recreational use has generally conformed to the existing configuration and flow patterns of the system and the availability of stored and flowing water. This has been primarily related to recreational and Tribal fishing and recreational boating and other water related recreation. It would be assumed that the objective of this study, the identification of potential storage sites would not have a significant negative impact on either of these uses. Any new storage facility will need to obtain water in a manner that will not jeopardize fish habitat and could be used to enhance both the native and anadromous fisheries. Since this study does not address additional mainstream storage, the existing and/or future increase or new storage on the Columbia River itself is not an issue. Table 3-1 provides a summary of current water use. Note that the very large value for hydropower represents active storage in the system, not necessarily the total demand in any given year. Although annual demand would necessarily be somewhat less, it nonetheless represents a very large non-consumptive water use.

M&I uses of the Columbia River are minor when compared to the agriculture and power generation demands. In Washington State, there are 15 communities with a population greater than 10,000 within the study area 10-mile corridor and within 50 miles of the eleven initial sites considered viable for storage. Of these, only four, Richland, West Richland, Pasco, and Kennewick (all in the Tri-Cities area) are adjacent to and currently utilize the river directly as a municipal water supply. In addition, several larger industries have water rights to river water. According to the state water right information, the current total combined municipal and industrial water rights for Columbia River water is approximately 337,000 acre-feet annually, or about 7.3 percent of annual existing Columbia River water rights. The value of M&I water is highly variable, ranging from a few dollars to as much as $452/acre-foot.

Table 3-1. Estimated Columbia River Annual Water Needs for Agriculture, Municipal and Industrial, and Fish Flows

Type of Permit	Irrigation[a]	M&I[a]	Fish Flows[a]
Drought Permits	29,000	4,000	17,000
Permits Issued as of 2003	39,000	89,000	64,000
Pending Applications	237,000	33,000	135,000
Projected Future Growth	47,000	7,000	27,000
Total	**352,000**	**133,000**	**243,000**

Notes:
[a] All flows are in acre-feet/year.
[b] Total in-stream flow represents existing potential generation capacity from storage.
Source: Washington Department of Ecology and Washington Department of Fish and Wildlife, 2004, Draft Environmental Impact Statement, Columbia River Mainstem Water Management Program, Publication No. 04-11-031.

The largest consumptive use of water is agriculture. The net monetary value of irrigation water is somewhat variable, ranging from $11/acre-foot to $69/acre-foot. This high variability in net monetary value results from the range of returns on crops. Low-end returns occur for such high-demand, low-value crops as alfalfa, wheat, barley, and potatoes, which consume most of the irrigation demand. These crops provide low yield relative to the water required for irrigation and are profitable only because of the high production volumes that can be obtained from irrigated crops. High value crops such as grape production for wine and certain orchard or vegetable crops consume relatively small amounts of irrigation water but yield high returns for the investment. It has been projected that shifting crop patterns, particularly expansion of irrigated acreage, will result in a larger proportion of Washington irrigated land used for more profitable orchards.

Over 3 million acre-feet/year of Columbia River water is designated for irrigation in Washington State. Within the eastern Washington study area, the largest water users include the Columbia Basin Project's Grand Coulee – Roosevelt Lake system, which irrigates over 600,000 acres, and the Yakima Valley irrigates over 500,000 acres using both Columbia and Yakima River water. The irrigated land associated with these programs have been under drought conditions for six of the past 13 years, reducing the availability of water for some junior and senior water rights in order to meet fish and wildlife needs. Additional Columbia River water storage could supplement summer irrigation needs to maintain existing water demands without impacting the instream fish requirements. This would allow more water to remain in the river during the late spring and summer months, which will benefit migrating fish by providing lower water temperature and higher instream flows.

The proposed Columbia River Initiative proposed by former State of Washington Governor Locke would have required that one-third of the water obtained by the State of Washington be held in State Trust and be left in the river for fish habitat improvement. Therefore, if the 728,000 acre-feet that the initiative was seeking were realized, up to 242,000 acre-feet would have been dedicated to fish and wildlife. The remaining 486,000 acre-feet would be available for out of stream (consumptive) uses.

According to a University of Washington study (January 12, 2004), up to 92,000 acre-feet per year will be required within the next 20 years to meet the growing M&I demand in the area. This includes approximately 81,000 acre-feet per year for existing applicants and an assumed 11,000 acre-feet per year for new applications for water rights.

Hydropower is the major contributor to the electrical power system in the northwest. In 2002 and 2003, hydropower contributed almost 75 percent of the energy used in Washington, 80 percent of the energy used in the Pacific Northwest, and about a third of the energy used in the continental United States. Any effort to provide additional instream flow for non-consumptive water use would have the added benefit of contributing to the potential for power generation. However, this is dependent upon timing. Water withdrawals for new storage will have to occur when "excess" flow is available and not required for other beneficial uses. If withdrawal occurs at a time of lower power demand (i.e. late fall) then the system may be benefited by summer releases. If withdrawals were to occur in winter when demand for electrical energy is high, then the net useful generation capacity could be negatively affected. Water for power generation has a monetary value (ranging from $5.64/acre-foot to $38.53/acre-foot).

One complication of the current system is that the four major water uses (agriculture, M&I, fish flows, and hydropower generation) require water storage and/or releases at conflicting times. Power demand is highest in summer and winter and is facilitated by larger releases of flow, whereas irrigation demand from reservoirs is highest in summer; the lowering of mainstream reservoirs associated with hydropower generation conflicts with the need for available storage for irrigation during late spring and summer. Similarly, fish flows may require releases in late spring, summer, and early fall, which may lower reservoirs before or during periods of high agricultural demand. Fish passage releases also may lower reservoir levels prior to periods of hydropower demand. Off-stream storage could provide a mechanism for augmenting flows to mitigate conflicts between seasonal water demands.

Population and economic growth in the Columbia River Basin will require increases in demand for M&I water, hydroelectric power, and recreation. Water for facilitating anadromous fish habitat and migration, whether mandated by law or implemented as part of wildlife agency management practices, also will require periodic in-stream flow demands that sometimes occur during periods of high demand on agriculture, hydropower, and recreation. Storage of Columbia River water during periods when flows exceed these demands would help facilitate management of each of these resources to make the water available when needed.

4.0 ECONOMIC BENEFITS/COSTS OF PROVIDING ADDITIONAL STORAGE WATER TO SATISFY IDENTIFIED NEEDS

4.1 INTRODUCTION

Increased demand for Columbia River water imposes conflicts with existing and future water uses and related economies as well as the health and viability of the river system itself. Several previous economic studies of economic benefits and costs resulting from additional diversions and storage of Columbia River water were located and evaluated. These studies are listed in the Reference section of this investigation. Review of these studies identified economic benefits as well as disadvantages that would accrue to local, state and regional economies resulting from increased water diversions and storage.

This section focuses on the economic consequences of increased water diversions and storage in the immediate vicinity (as defined in the work scope of this investigation) of the mainstem Columbia River in Washington State. Included are projected economic impacts on agricultural production, municipal, rural and industrial water supplies, hydropower generation, flood control and river navigation, commercial and recreational fishing and wildlife, other recreational uses and regional impacts. These economic benefits are discussed by use categories in the following paragraphs and are summaries from "The Economics of Columbia River Initiative", a 2004 joint University of Washington and Seattle University (UW & SU) economic study for the Washington Department of Ecology (DOE), published in 2004.

The UW and SU study evaluated five different management scenarios, i.e., "Columbia River Initiative Management Scenarios," with respect economic impacts to Washington's agricultural production from additional diversions and storage above current levels. Scenario 1 addressed new water rights and storage, up to 1 million acre-feet of additional water, for interruptible agricultural users to convert to non-interruptible use, if they met best management practices (BMP) efficiency standards, including metering. Scenarios 2 & 3 evaluated new water rights and storage, with up to 1 million acre-feet of additional water , but with modified market-based water economies, setting arbitrary unit values per acre-foot. These two scenarios also require 300,000 acre-feet of the 1 M acre-feet to be withheld until 80% of the water users comply with the BMPs. Scenario 4 allowed no new diversions of additional water (and storage) but did permit the exchange of rights between new and existing users. Scenario 5 maintained the status quo with no new diversions.

4.2 AGRICULTURAL PRODUCTION

A major impact of new water diversions and storage is the expansion of crop production, in the Columbia Basin. Assuming that crop prices remain at current levels, and that the costs of production are accurately estimated, the gross revenue of new crops grown as a result of increased water availability significantly increases from current levels. All economic studies reviewed for this investigation note that when the agriculture sector expands, all related economic sectors (e.g. suppliers, processors and other related industries) will expand in unison. Further, the increased incomes by wage earners in the expanding sectors will spur increased sales of a wide variety of consumer goods, and this will cause additional economic expansion in the regional economy.

The UW and SU study concluded that Scenarios 1, 2 and 3 which provided for up to 1 million acre-feet of new water diversions could result in up to a 20 percent expansion of Washington's agricultural economy.

This expansion could create about 45,000 new jobs and an estimated additional $2 billion, presumably in 2003 dollars, to the state's economy. Scenario 4 would have positive economic impact but could not be quantified. Scenario 5 would have no additional economic impact.

4.3 MUNICIPAL, RURAL AND INDUSTRIAL USES

Municipal, rural and industrial (MR&I) use of water is a relatively small portion of the total withdrawals from the river but they are high-value and high priority uses that facilitate the expansion of towns and industries in areas where agricultural production is expected to grow. For example, the population of the Tri-City area, the main population center in this study area, grew by about 30 percent in the past 10 years. It can be assumed that MR&I water use would need to increase by about 30 percent to keep up with growth demands over that period of time. In all five of the management scenarios, the same quantiry of MR&I water is assumed to be allocated because of the high valued use.

4.4 HYDROPOWER GENERATION

Each new diversion will decrease the stream flow in the Columbia River downstream of the diversion point. This reduced flow will cause a reduction in hydroelectric power production at dams on the mainstem of the Columbia River with corresponding economic impacts. In addition to the loss of hydropower generation, there would be an increase in power consumption associated with pumping the increased divrsions in Scenarios 1-3. Beyond these basic statements, calculating the economic impacts of the management scenarios is complex. The UW and SU study found that Scenario 1 conditions could result in lost hydropower revenues ranging from about $18 million to $20 million. The modified assumptions of Scenarios 2 and 3result in either the same impacts of Scenario 1or somewhat lower costs. Scenario 4 would cause negligible loss of hydropower production, because all new water rights would be offset through transfers, conservation, and/or new storage. There would be no loss of hydropower generation with Scenario 5, the "no new diversions" option.

4.5 FLOOD CONTROL AND RIVER NAVIGATION

Flood control and river navigation are important purposes served by the Federal dams in the lower Columbia and Snake Rivers. None of the UW and SU study scenarios would be detrimental to flood control efforts because increased diversions result in less in-stream water, but the scenarion with the greatest chance of flooding is Scenario 5. New water diversions for storage are not expected to have any perceptible effects on flood control activities

Shallow draft river navigation (barging) occurs in the reservoir system from Bonneville Dam to the Tri-cities area, and up the Snake River as far as Lewiston, Idaho. Barging is not expected to be significantly affected because reservoir levels are maintained to exceed levels necessary for lock operation at dams even in dry years. Deep-draft navigation in the lower Columbia River below Bonneville dam is not expected to be affected by new diversions, because the minimum flow needed to maintain the shipping channel depth would not be jeopardized by the decreases in flow caused by the storage diversions this study is considering. The SU and UW report summarizes that there is unlikely to be any economic impact on the current Columbia-Snake River navigation system from additional withdrawals of mainstem water.

4.6 COMMERCIAL AND RECREATIONAL FISHING AND WILDLIFE

Commercial and recreational fishing may be harmed by increased diversions from the Columbia River and its tributaries. This would occur if mortality during downstream migration of juvenile fish, or upstream migration of adult fish, increases as flows decline. There is currently no scientific consensus on flow-mortality relationships. Separate research by qualified researchers, should independendly evaluate this risk. Accordingly, the UW and SU study made no attempt to quantify possible economic impacts to the fishery.

4.7 PASSIVE VALUES

Passive values or "existence values" transcend market-based values and represent what people are willing to pay for something, even if they do not expect to consume or use it. Passive use values are particularly significant for public use goods that are unique and scarce and could be considered quality of life enhancements. Certain fish populations in the Columbia River system are examples of objects that qualify as having passive use value. Diminished river flows would erode passive values while increased flows would build them. The UW and SU study concluded that the most likely significant passive values affected by increase diversions will pertain to changes in salmon and steelhead runs. The magnitude of these changes if any, are being investigated by a separate research group.

The economic studies reviewed did not consider a wider range of Columbia River mainstem issues relating to neighboring states, Canada, Native American tribes, climate change or changing Federal court rulings.

5.0 IDENTIFIED STORAGE OPTIONS FOR OFF-CHANNEL SITES OF 300,000 ACRE-FEET OR GREATER

5.1 METHODOLOGY

5.1.1 Preliminary Site Identification

Potential storage sites were identified based on the following assumptions:

- Minimum active storage of 300,000 acre-feet
- Maximum shortest pumping distance ±10 miles from mainstem Columbia River
- Maximum 800 feet of total lift from Columbia River required for reservoir fill
- Impoundment would not cross into Canada
- No towns or cities would be inundated

Dam maximum elevations were identified by impoundment within the highest contour possible. At some sites, there would be need for confining saddle dams to achieve the minimum storage volume or to prevent uncontrolled inundation across a topographical depression.

Preliminary site identification was made without consideration of engineering criteria or feasibility, geology, political boundaries, roads, railroads or utilities within the potential reservoir boundary. Initial dam siting and top elevation was based on maximum practical reservoir volume and did not consider engineering criteria or feasibility or total lift required.

The dams and potential storage sites identified during this study are shown in Map 1. The map presents each identified off-channel dam and storage site along the Columbia River in Washington from upstream to downstream, and also shows the existing mainstem Columbia River dams.

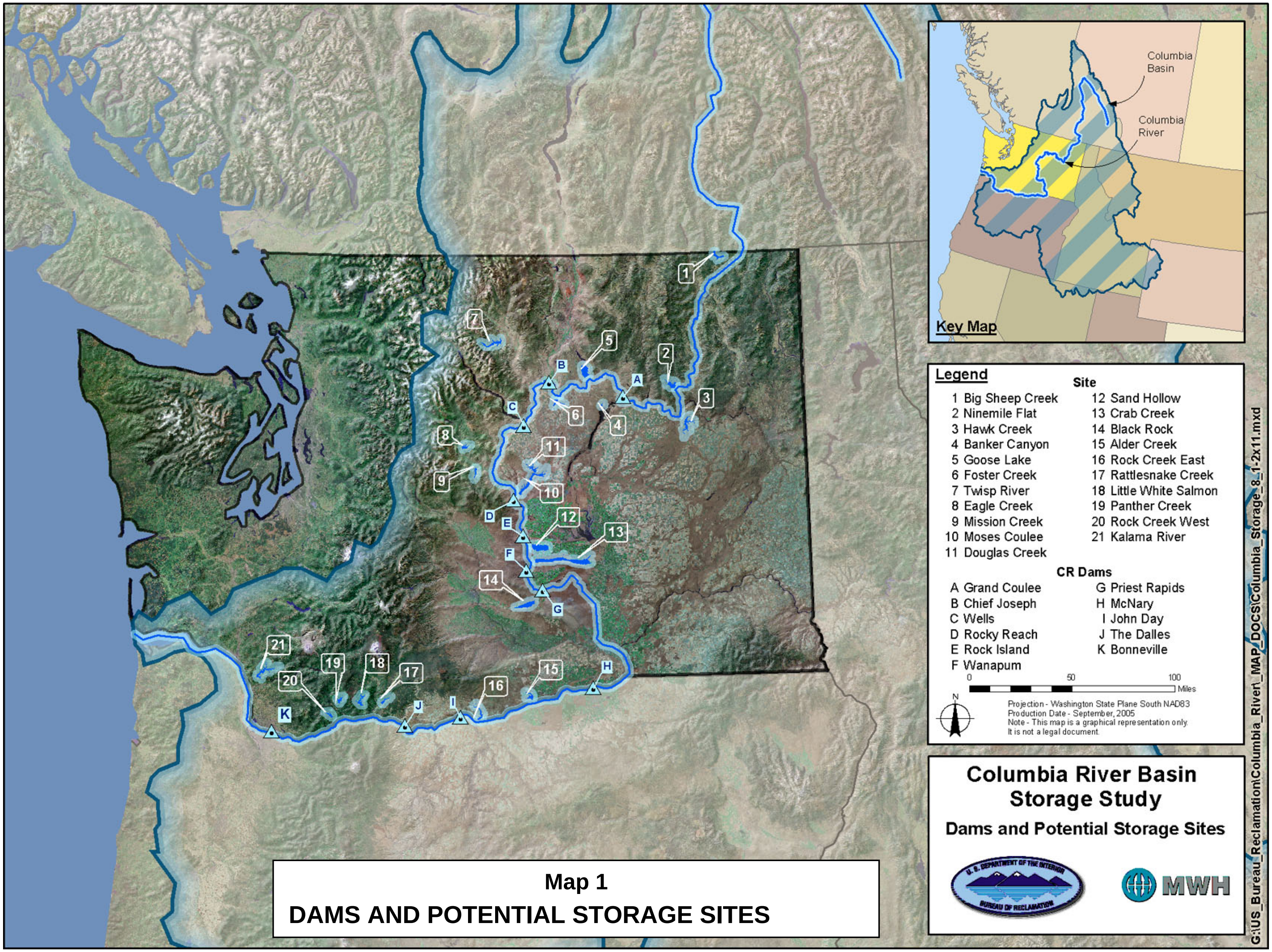
5.1.2 Dam and Reservoir Sizes

Potential reservoir margins were digitized in ArcMap GIS from TOPO! 1:24,000 scale topographic maps. For ease of processing, major contour lines were selected for digitization. Contour intervals varied from 10 to 40 feet. Potential reservoir surface areas were calculated in the GIS. A rough estimate of potential reservoir volume was calculated by developing several topographic layers within the reservoir area, calculating the volume of each layer and summing all layers to obtain the reservoir volume. A number of sites evaluated did not meet the active storage assumption and were not included in the preliminary list of potential storage sites.

Nine initially identified potential sites were not consistent with all of the assumptions and were not analyzed in detail. Eleven potential storage sites that satisfied all of the assumptions were analyzed further with the ArcMap Spatial Analyst extension to create detailed elevation-capacity-area curves from digital elevation model (DEM) topography of the sites.

5.1.3 Water Availability

The Bonneville Power Administration (BPA) has developed a computer model called HYDROSIM (BPA, 1992) that models operations on the Columbia River for a 50-year period of simulation from 1929 through 1978. The model operates on a monthly time increment except for the months of August and



Map 1
DAMS AND POTENTIAL STORAGE SITES

April, which are modeled in half-month time increments because these can be months of substantial flow change on the Columbia. Model output, including flow, reservoir elevation, and energy generation, is available at 21 dams along the Columbia River and tributaries. The Columbia River flows presented in this section are based on output from the HYDROSIM model, which was provided to MWH by the USBR as obtained from the BPA.

HYDROSIM can be used to determine critical rule curves and the availability of firm energy, or to examine operations under other historical streamflow conditions. In application to the subject of water availability on the mainstem Columbia River, HYDROSIM was used to simulate Columbia River flows under the condition of the December 2000 Federal Columbia River Power System (FCRPS) Biological Opinion (2000 BiOp). The 2000 *Biological Opinion* (NMFS, 2000) report was the result of an Endangered Species Act consultation conducted by the National Marine Fisheries Service.

Water diversions for off-channel storage would typically be made from the reservoir impounded by one of the mainstem dams of the Columbia River. The most upstream dam on the mainstem Columbia River in Washington and the only mainstem dam with substantial active storage is Grand Coulee Dam, while the most downstream mainstem Columbia River dam is Bonneville Dam. The long-term annual average flow of the Columbia River ranges from about 79,000,000 acre-feet per year in Franklin D. Roosevelt Lake behind Grand Coulee Dam to about 135,000,000 acre-feet per year in Bonneville Lake behind Bonneville Dam. Figure 5-1 provides the average, maximum, and minimum annual flow in acre-feet based on water years 1929 through 1978.

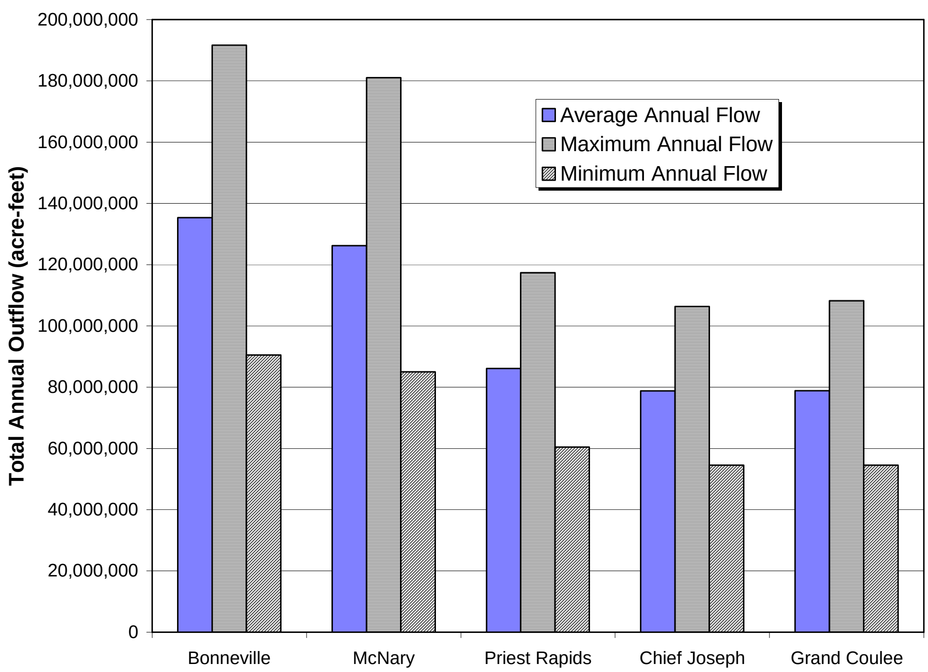


Figure 5-1: Total Annual Outflow (acre-feet) at Mainstem Dams

Reservoir storage volumes are typically quoted in acre-feet while waterway and pumping flow rates are quoted in cubic feet per second (cfs). To provide a reference of river flow rates in acre-feet per year to the waterway and pumping flow rates in cubic feet per second, the average, maximum, and minimum Columbia River outflow rates at the mainstem dams are also presented in cfs on Figure 5-2. At Bonneville Dam, for example, the long-term average outflow of 187,000 cfs corresponds to a long-term average annual outflow of 135,000,000 acre-feet per year.

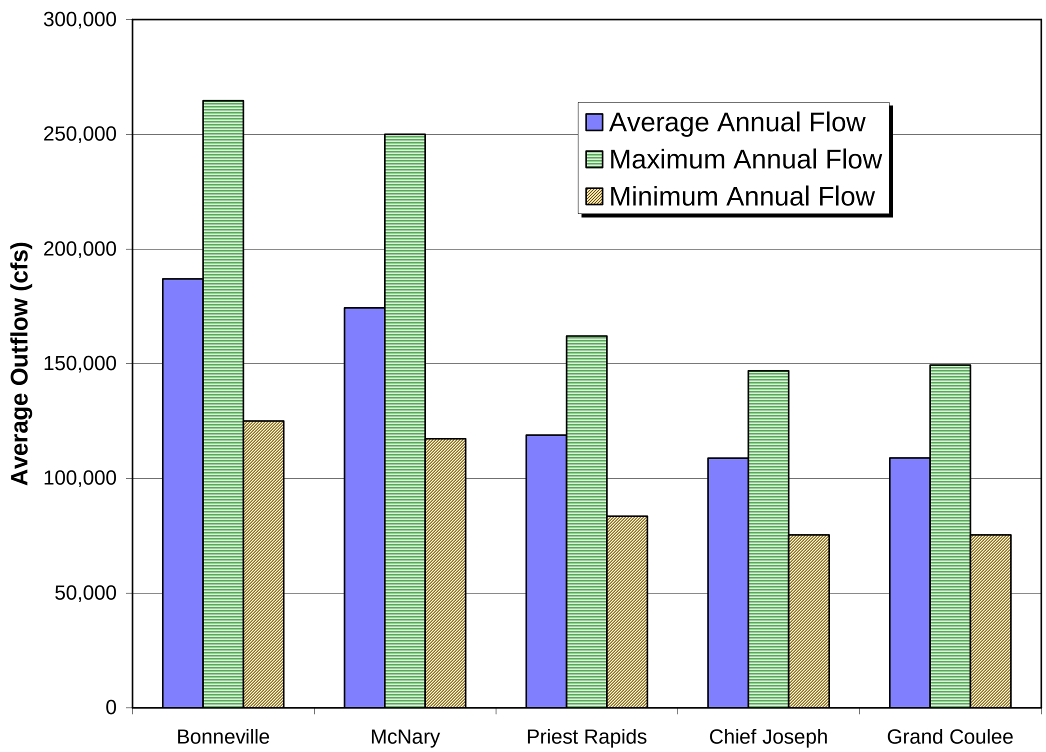


Figure 5-2: Average Outflow (cfs) at Mainstem Dams

Figure 5-3 presents the long-term average seasonal total flow of the Columbia River at three dams representing the upper, lower, and mid-Columbia river segments. River flow peaks in the April through July period with a secondary peak in average flows during January.

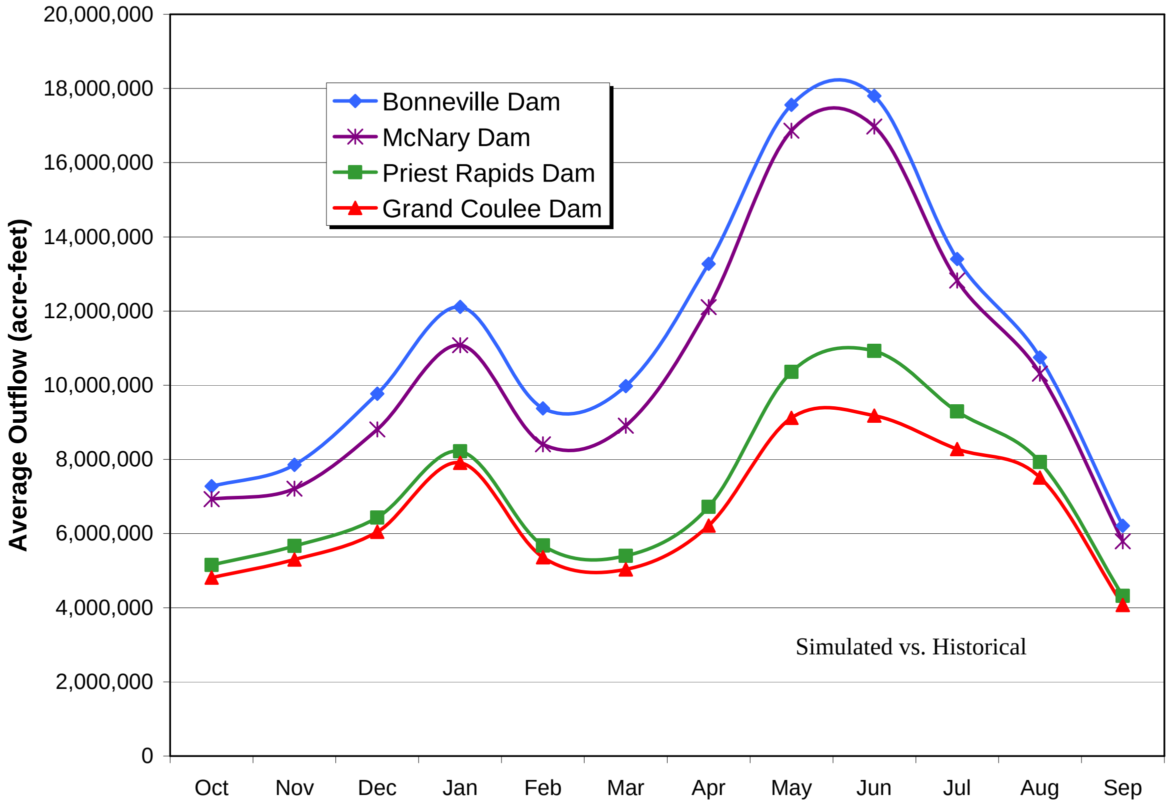


Figure 5-3: Average Monthly Simulated Flows at Four Dams on the Columbia River

The 1929-1978 data set used by HYDROSIM is modified to the 1980 level of agricultural diversions. About 7.3 million acres are irrigated in the Columbia River basin, of which 7.1 million acres are in the USA. Irrigation uses approximately 9 percent of the annual flow at The Dalles (BPA, 2001) and can be as high as 16 percent during low flow periods in July and August. The long-term average annual flow at The Dalles is 177,900 cfs, or about 129,000,000 acre-feet per year. The corresponding irrigation use would be about 16,000 cfs or approximately 12,000,000 acre-feet per year. Much of this water eventually finds its way back into the rivers as irrigation return flows, although the returns are not credited against the original withdrawal figures.

The HYDROSIM model does not directly determine water available for diversion to offstream storage projects. The model operates to requirements of the 2000 BiOp, including instream flow requirements. The minimum flow objectives specified in the 2000 BiOp are on the Snake River at Lower Granite Dam, and on the Columbia River at McNary Dam, Priest Rapids Dam, and Bonneville Dam. The Columbia River target flows from the 2000 BiOp are summarized in Table 5-1. There is variation in flow requirements for some months, depending on the type of flow year (wet or dry). At the current appraisal-level of analysis, water in the Columbia River in excess of the flow targets is assumed to be available for diversion to offstream storage. This is the same assumption made by the U.S. Bureau of Reclamation (USBR, 2004) in their appraisal-level assessment of water availability for the potential Black Rock Reservoir. For Black Rock, the USBR determined water availability from the reservoir behind Priest Rapids Dam.

Table 5-1. Target Flows (cfs) from the 2000 Biological Opinion			
Month	**Columbia River at Priest Rapids Dam**	**Columbia River at McNary Dam**	**Columbia River at Bonneville Dam**
January	-----	-----	125,000 to 160,000
February	-----	-----	125,000 to 160,000
March	-----	-----	125,000 to 160,000
April	135,000	220,000 to 260,000	125,000 to 160,000
May	135,000	220,000 to 260,000	-----
June	135,000	220,000 to 260,000	-----
July	-----	200,000	-----
August	-----	200,000	-----
September	-----	-----	-----
October	-----	-----	-----
November	-----	-----	125,000 to 160,000
December	-----	-----	125,000 to 160,000

For an appraisal-level assessment, water availability for diversion could be determined by doing a flow frequency analysis of long-term flows in the Columbia River. The assumption would be that water would be available for diversion at some level of higher flows during each month. This method was not used in the current study because a direct accounting of the water reserved for the flow targets is a more detailed and accurate method of estimating water availability that utilizes the most recent simulations of Columbia River operations.

Figure 5-4 shows the governing Columbia River 2000 BiOp target flows in relation to the average flow on a monthly basis. As a simplifying assumption where there is a year to year variation in the target flows, the April through June target flows were assumed to be 260,000 cfs at McNary Dam and 130,000 cfs at Bonneville Dam in the November through March period. A minimum flow of 55,000 cfs at Vernita Bar below Priest Rapids Dam also is generally recognized during October. Considering the average release at Priest Rapids Dam during October is about 84,000 cfs, this requirement is not significant. To provide a target flow in the remaining month of September that had no specified target flow, the minimum flow of 55,000 cfs below Priest Rapids Dam also was assumed to apply during September.

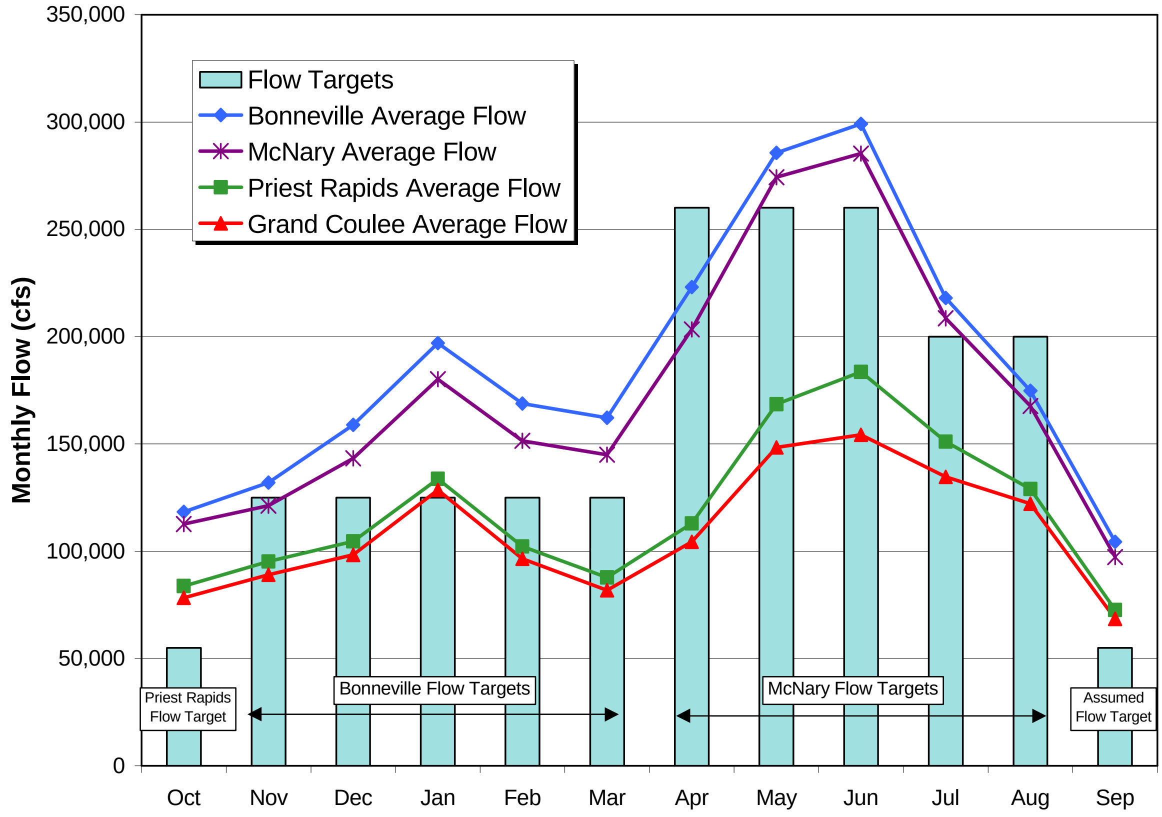


Figure 5-4: Average Monthly Flows and Flow Targets

The water availability for diversion to off-channel storage, as presented in more detail for each of the potential off-channel storage sites in the following sections, ranges from an average of about 20,000,000 acre-feet per year in Franklin D. Roosevelt Lake to about 26,000,000 acre-feet in Bonneville Lake. As presented on Figure 5-5, which includes maximum year, minimum year and long-term average water availability, there is a substantial range of water availability from year to year. The large variation in water availability from year to year indicates the need for off-channel storage to provide a much more reliable water yield in every year.

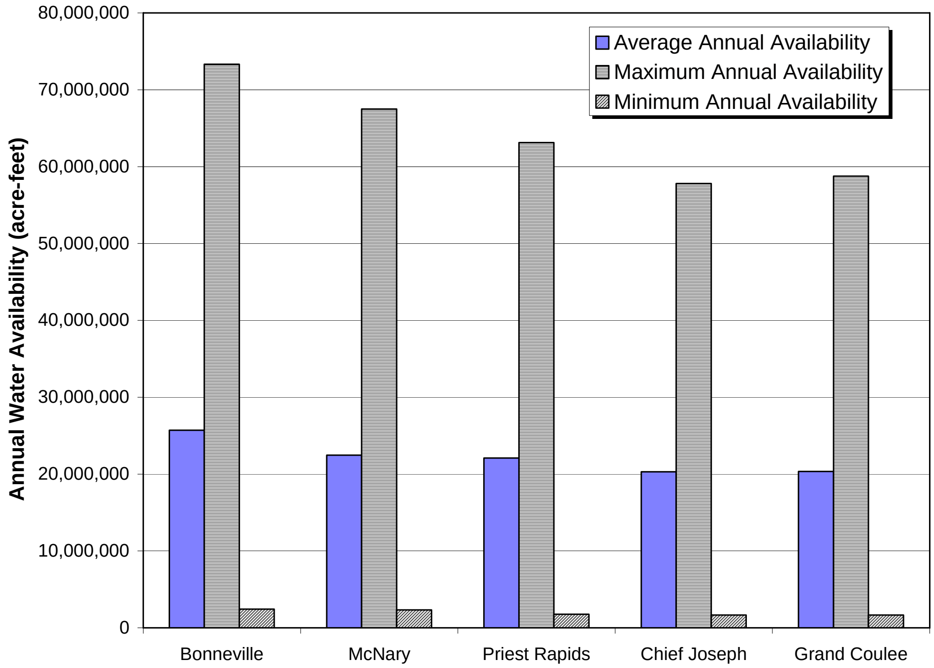


Figure 5-5: Annual Flow Availability

Figure 5-6 shows the monthly water availability in acre-feet at three dams along the mainstem Columbia River. On a long-term average basis, January would have the greatest quantity of water available and August would have the least water available. On a reliability basis, September and October are the best months for water availability, with water available for diversion during those months in virtually every year.

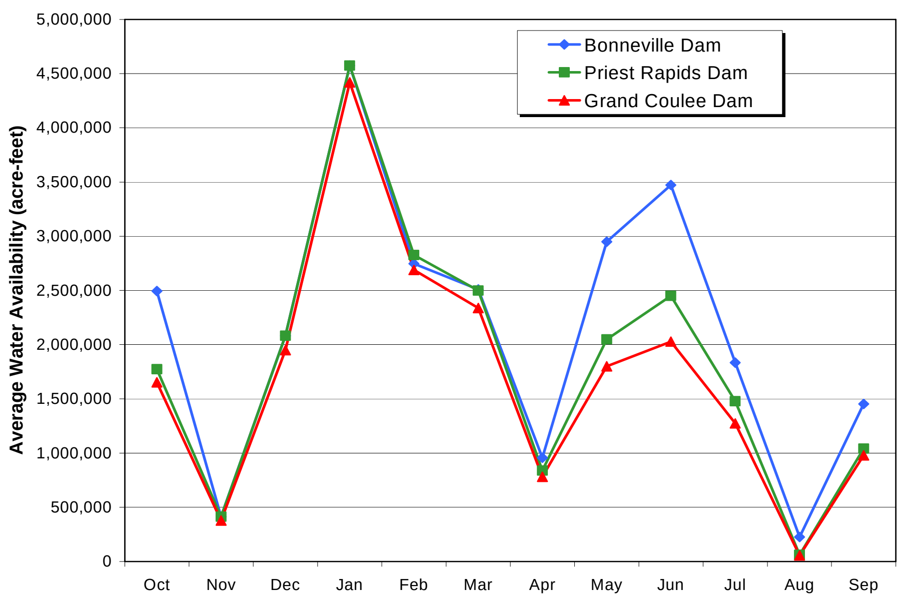


Figure 5-6: Monthly Flow Availability at Three Dams on the Columbia River

5.1.4 Pump and Waterway Sizes

The final determination of pump capacity from the Columbia River to the off-channel storage reservoir will be dependent on the magnitude and timing of water needs, the reservoir storage capacity, and the magnitude and timing of water availability from the Columbia River. At the current stage of studies, the magnitude and timing of the water needs that could be assigned to each of the potential storage sites is unknown. For a given water demand and pattern to be served by a reservoir, a relationship between reservoir size and pumping capacity can be developed. For a fixed water demand, there generally is a trade-off between pumping capacity and active reservoir storage volume that can be optimized. When the magnitude of water demand is unknown, a reasonable assumption is that pumping capacity will be directly related to active storage capacity.

Based on a review of water availability and previous studies, it was assumed that for reservoirs with active storage of 1 million acre-feet and smaller, the pump capacity will be sized to entirely fill the active storage in four months of continuous pumping. For a reservoir with 2 million acre-feet of active storage, the requirement will be to have pumping capacity to fill the reservoir storage in six months of continuous pumping. For reservoirs between 1 and 2 million acre-feet of active storage, pumping capacity will be based on a required time to fill the reservoir that varies linearly between 4 and 6 months. In a similar manner, for reservoirs with active storage greater than 2 million acre-feet, the required time to fill will increase linearly by an additional two months for each one million acre-feet of additional storage.

Waterway sizes from the Columbia River to the off-channel storage sites will be directly related to the pumping capacity. The waterways will be sized to carry the maximum pumping capacity at a maximum velocity of 15 ft/sec. At the current earliest stage of studies, this maximum velocity criterion will be applicable to both pipelines and tunnels, which are collectively referred to as waterways.

Results of the pump and waterway sizing for each reservoir site are presented in Table 5-2. The value for time to completely fill the entire active storage is based on assumed continuous pumping at pump capacity. The actual time to fill active storage will depend on water availability and the magnitude of the deficit in active storage.

Table 5-2. Pump Capacity and Waterway Diameter for Each Reservoir Site

Site	Maximum Water Level (feet)	Total Storage (acre-feet)	Active Storage (acre-feet)	Time to Fill Active Storage (months) [1]	Pump Capacity (cfs)	Pump Static Head (feet)	Waterway Diameter (feet)	Waterway Length (miles)
Ninemile Flat	2100	1,030,000	930,000	4	3,900	810	18	0.86
Hawk Creek	2000	1,550,000	1,400,000	4.8	4,800	710	20	1
Goose Lake	1750	3,720,000	3,350,000	8.7	6,400	450	23	0.7
Foster Creek	1700	1,340,000	1,210,000	4.4	4,500	820	20	1.75
Mission Creek	1600	470,000	420,000	4	1,700	810	12	7.7
Moses Coulee	1400	4,130,000	3,720,000	9.4	6,500	830	23	2.58
Sand Hollow	1200	1,230,000	1,110,000	4.2	4,400	630	19	2.38
Crab Creek	700	2,650,000	2,390,000	6.8	5,800	210	22	2.5
Alder Creek	700	330,000	300,000	4	1,200	430	10	1.25
Rock Creek East	900	1,000,000	900,000	4	3,700	635	18	0.58
Kalama River	800	1,185,000	1,070,000	4.1	4,300	785	19	6.1

Note: 1 Based on continuous pumping at pump capacity.

5.1.5 Pre-Appraisal-Level Cost Estimates

Pre-appraisal-level field (direct) construction cost estimates were prepared as one parameter to be included in the evaluation criteria recommended in Section 7.0 to assess the viability for additional investigations. Field costs are not the total cost necessary to complete a project. Field construction costs are limited to the costs of construction contracts and do not include costs such as preparing final engineering designs and specifications, land acquisition, regulatory compliance and permitting activities, environmental mitigation and monitoring and construction contract administration and management. The total estimated project costs would be substantially larger than the estimated construction costs. All field costs are in June 2004 price level dollars and include allowances for mobilization, unlisted items and contingencies. Industry practice rule-of-thumb percentages were used to approximate these allowances as follows:

- Mobilization – the assumed 5 percent of the subtotal direct construction cost is based on past experience of similar projects.
- Unlisted Items – based on the level of detail provided for this study's cost estimates, the unlisted items is set at 15 percent of the subtotal direct construction cost plus mobilization.
- Contingencies – based on general knowledge of the conditions at the various sites, the contingency is set at 25 percent of the direct construction cost plus mobilization and unlisted items.

The pre-appraisal-level costs were prepared using an abbreviated technique of scaling (see Appendix B) based on previously determined costs for the large and small reservoir options at Black Rock Dam and Reservoir (Bureau of Reclamation June 2004) and Wymer Dam and Reservoir (Tri-County Water Resources Agency November 2002 adjusted to June 2004).

Indirect costs for land acquisition, environmental and permitting, engineering-design and construction management is typically estimated to be from 20 percent to 35 percent of the direct construction costs. These costs were added to the direct construction costs to determine the estimated total construction costs.

The pre-appraisal level construction cost estimates do not include costs for constructing power generating facilities and transmission facilities at potential off-stream surface storage sites. All of the potential off-stream storage sites have the potential for power generation upon release of stored water. The existing literature review performed as part of the pre-appraisal study did not result in identifying any potential power generation from off-stream storage sites. Evaluation of power generation from identified potential off-stream surface storage sites is dependent on the water storage and release schedule and other factors, and is beyond the scope of the analysis for the pre-appraisal study. Potential power generation and associated cost estimates for power generation and transmission infrastructure should be evaluated in appraisal-level studies and subsequent feasibility studies on potential off-stream surface storage sites.

Pre-appraisal-level construction cost estimates were prepared as part of this study solely for screening alternative projects relative to each other in a selection process to determine which, if any, project(s) may be suited for a future feasibility-level study. Total estimated costs can only be accurately determined through a comprehensive process of feasibility studies and detailed design engineering, which remain to be accomplished in the future.

5.2 SURFACE SITES

5.2.1 Big Sheep Creek Dam and Reservoir Site

The Big Sheep Creek Dam and Reservoir Site is located west of the Columbia River in Stevens County, just south of the United States – Canada border. At the minimum required active storage volume of 300,000 acre-feet, the potential reservoir would extend across the border in the Big Sheep Creek/Corral Creek drainage. This would not be acceptable under the assumptions and the site was not analyzed in detail.

5.2.2 Ninemile Flat Dam and Reservoir Site

5.2.2.1 Site Location

The Ninemile Flat site is located west of the Columbia River, approximately 55 river miles upstream of Grand Coulee Dam. The dam and reservoir would be located in south Ferry County, in Townships 29 and 30 North, Ranges 35 and 36 East on the USGS 1:100,000 scale Nespelem, Washington topographic quadrangle (see Site 2 on Map 1). Map 2 shows the potential Ninemile Flat Dam and Reservoir location in Ferry County. The site would be located entirely within the Colville Indian Reservation boundary.

5.2.2.2 Previous Investigations

None identified.

5.2.2.3 Current Analysis

The Ninemile Flat dam and reservoir site would have a full-pool elevation at 2,100 feet MSL and would inundate portions of Ninemile Creek, its South Fork and Jerred creeks, and the large low-relief Ninemile Flat (see Map 3). Figure 5-7 shows the elevation-capacity-area curves for the potential Ninemile Flat reservoir. Figure 5-8 shows a cross-section of the proposed dam site looking downstream.

Reservoir Volume

Total potential storage volume is estimated at approximately 1,030,000 acre-feet at elevation 2,100 feet MSL. Usable active storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 930,000 acre-feet.

Inundated Area

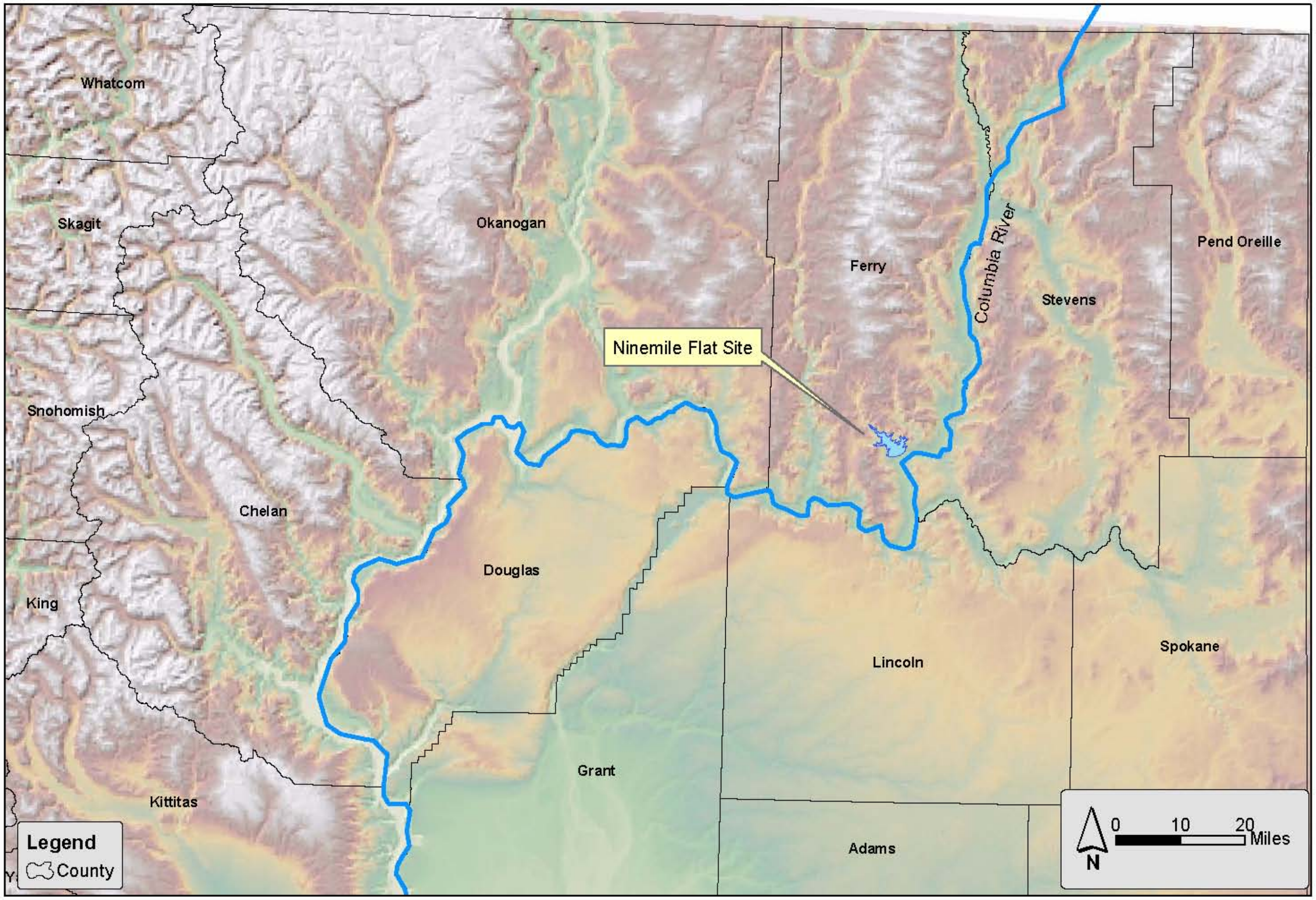
The inundated surface area at full-pool elevation would be approximately 6,120 acres.

Dam Size

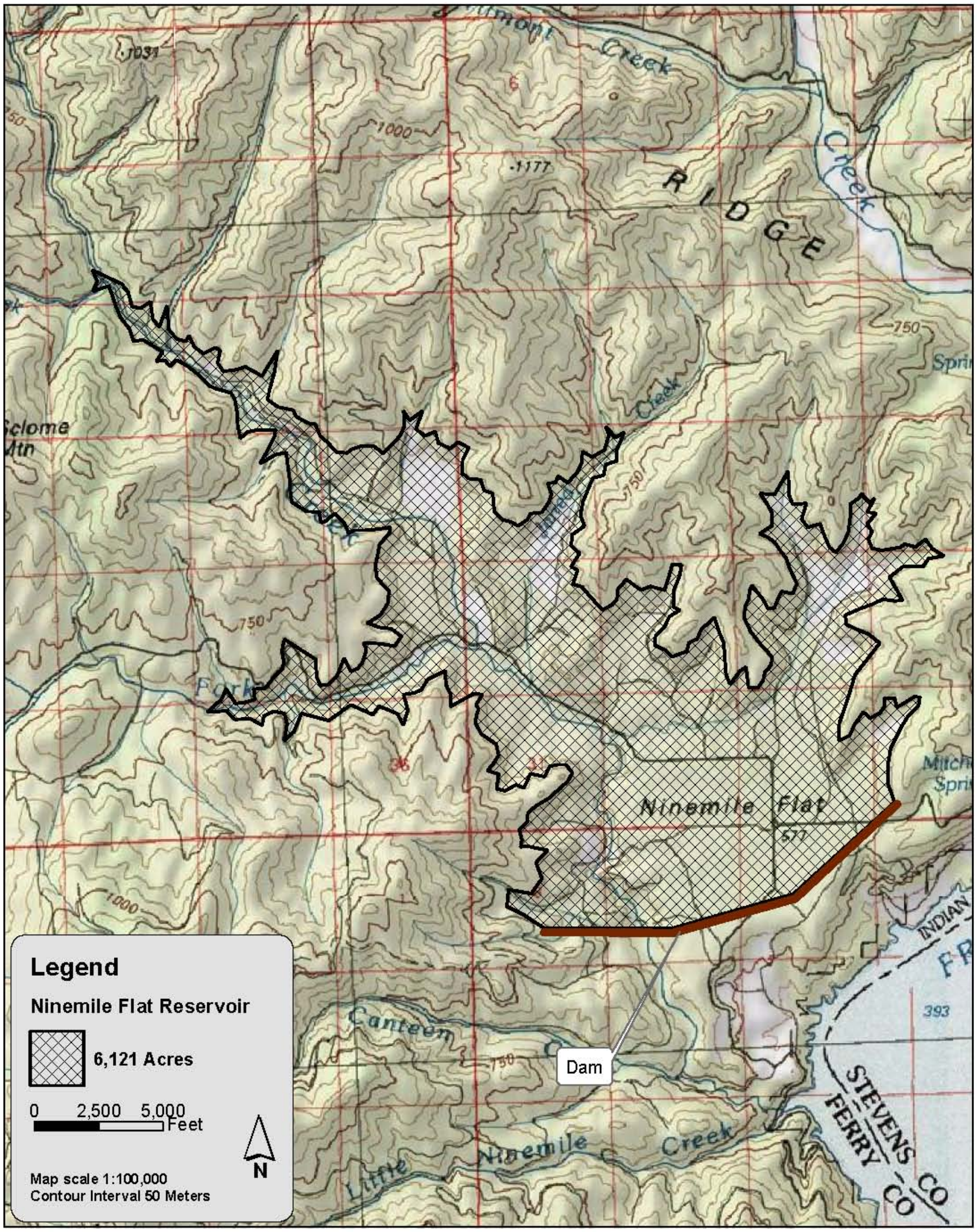
The dam would be located across a broad, gently sloping area at the south end of Ninemile Flat. Throughout much of its length, it would be more like a saddle dam. The dam would be approximately 14,400 feet long by 160 to 210 feet high, including a 10-foot freeboard. Where the dam would cross the Ninemile Creek drainage, it would have a maximum height of approximately 380 feet (see Figure 5-8 for the dam cross section).

5.2.2.4 Water Sources and Availability

No flow data is available for Ninemile Creek. In comparison to the flow pumped from the Columbia River, natural inflows at the dam site would be negligible. The diversion point would be in Franklin D. Roosevelt Lake. The total outflow of the Columbia River at Grand Coulee Dam is presented in Table 5-3.



Map 2
Ninemile Flat Dam and Reservoir Location Map



Map 3
Ninemile Flat Dam and Reservoir Site Map

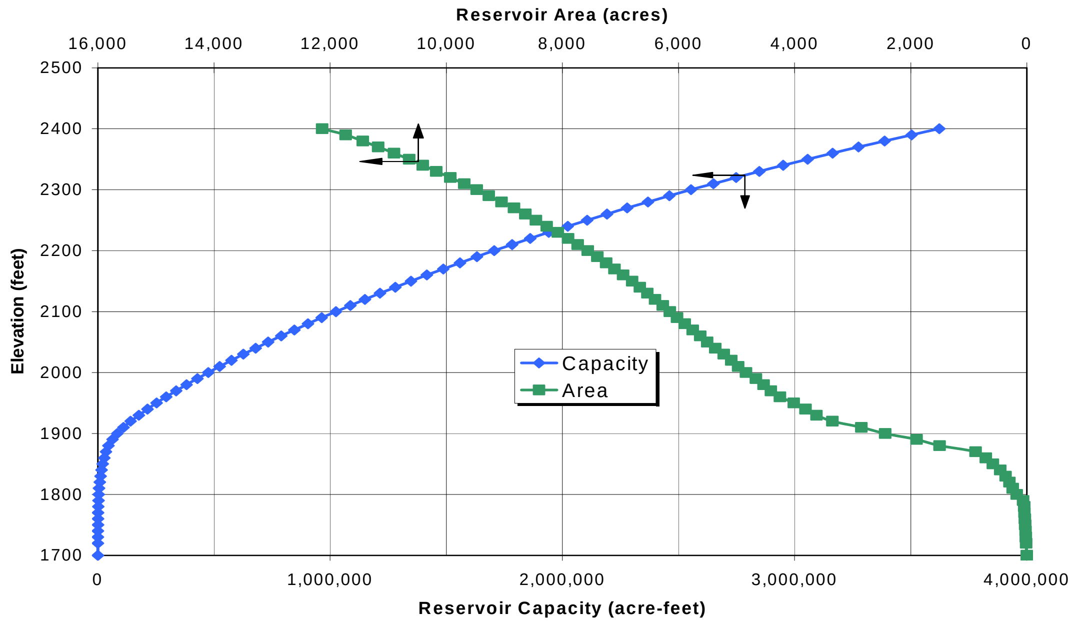


Figure 5-7. Ninemile Flat Reservoir Elevation-Capacity-Area Curves

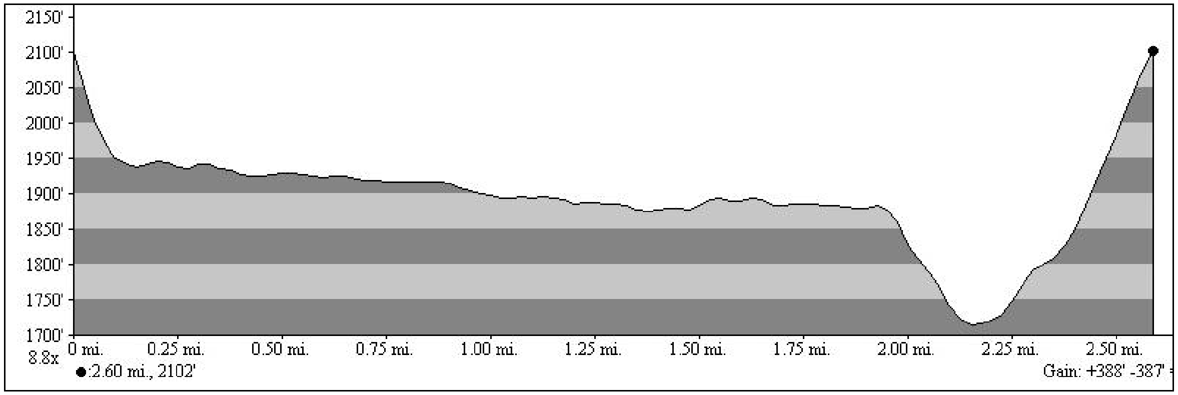


Figure 5-8. Ninemile Flat Dam Cross Section

Table 5-3. Total Columbia River Flow at Grand Coulee Dam (1000's of acre feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	4,339	5,358	5,352	6,325	3,389	3,742	1,899	1,832	3,507	5,006	6,115	3,154	2,961	3,697	56,677
1930	4,852	5,794	5,388	3,977	3,627	3,990	1,902	1,833	3,411	6,685	6,814	3,575	3,284	3,837	58,968
1931	4,726	5,696	5,944	3,786	3,387	3,806	1,869	1,784	4,510	7,095	5,997	3,644	3,265	4,180	59,691
1932	4,851	5,463	5,833	3,723	3,339	3,552	3,240	5,069	9,986	9,134	7,765	4,297	3,919	3,852	74,023
1933	4,607	4,557	6,417	9,365	7,669	3,614	2,322	3,062	9,021	11,645	12,163	4,179	4,740	4,350	87,710
1934	5,768	6,621	10,238	13,846	9,881	7,088	5,148	5,300	11,669	6,449	8,328	3,216	2,772	3,802	100,126
1935	4,615	4,660	5,792	9,081	8,372	3,268	2,370	3,381	7,979	7,825	8,417	4,324	3,162	3,902	77,147
1936	4,739	5,513	5,881	4,285	3,411	3,770	1,830	2,122	11,598	7,816	6,751	3,912	3,052	3,537	68,217
1937	4,778	5,689	5,777	4,333	3,679	4,045	1,971	1,986	3,862	5,128	6,058	3,627	2,842	3,610	57,384
1938	4,916	5,136	4,745	9,762	4,747	5,600	2,667	3,527	11,495	7,459	7,410	3,125	2,547	4,018	77,153
1939	4,559	5,303	4,963	6,766	3,512	3,780	1,771	2,341	9,100	6,804	6,591	4,027	3,154	3,620	66,292
1940	4,946	5,377	5,623	5,955	3,874	5,590	2,197	3,182	6,801	7,760	6,021	3,359	2,933	3,552	67,172
1941	4,567	4,823	5,812	6,590	3,102	3,949	1,520	2,000	5,503	6,665	4,951	3,127	2,977	3,736	59,322
1942	4,221	4,396	6,878	9,500	3,548	3,107	1,488	2,259	6,305	9,292	8,996	4,400	3,664	3,631	71,685
1943	4,602	4,742	4,857	7,261	4,864	5,113	4,242	4,028	11,688	8,188	7,510	3,901	3,463	3,412	77,872
1944	4,431	5,228	4,736	6,779	3,258	3,616	1,765	1,728	3,743	5,219	4,506	3,186	2,618	3,757	54,569
1945	4,545	5,428	5,672	3,527	3,197	3,618	1,734	1,720	5,638	7,674	6,413	3,232	3,113	3,302	58,815
1946	4,679	5,100	4,349	5,857	5,391	5,904	3,078	4,175	12,276	8,918	8,386	4,329	3,538	3,820	79,801
1947	3,988	4,734	6,901	8,913	5,863	7,170	2,280	3,854	9,651	8,427	8,309	4,335	3,034	3,723	81,182
1948	7,024	5,872	6,804	8,443	3,945	5,094	2,780	4,224	11,688	20,100	9,130	4,127	4,638	4,517	98,385
1949	4,579	4,849	5,598	6,991	4,390	6,401	1,898	4,675	9,563	7,808	5,423	3,129	2,435	3,103	70,842
1950	4,467	4,871	4,413	7,558	7,128	7,859	3,257	4,159	10,354	13,265	8,922	3,663	4,100	3,942	87,958
1951	5,168	5,808	8,094	10,625	8,717	6,041	3,259	4,774	13,546	6,933	9,587	4,152	4,147	4,235	95,086
1952	6,053	5,114	6,682	8,853	5,255	5,940	2,958	3,646	12,674	7,831	6,884	4,026	2,855	3,505	82,276
1953	4,466	5,529	5,349	5,039	6,211	3,587	1,720	2,629	9,535	10,615	8,962	4,116	3,392	3,792	74,942
1954	4,644	5,117	6,360	7,629	6,865	5,944	3,166	2,915	12,036	14,730	10,769	5,119	4,614	7,103	97,011
1955	5,229	5,836	6,876	5,756	3,650	3,847	1,816	1,794	5,966	14,414	12,903	4,195	4,595	3,723	80,601
1956	5,157	5,648	7,549	10,905	5,372	6,702	3,813	5,749	13,761	12,522	9,514	4,213	3,860	3,681	98,446
1957	4,637	4,813	6,017	8,223	3,585	3,857	3,735	3,318	10,173	11,938	7,114	3,471	2,778	3,582	77,239
1958	4,485	5,339	4,822	7,198	5,424	5,764	1,870	3,553	9,885	9,927	6,490	3,481	3,105	3,733	75,075
1959	4,398	5,245	6,756	10,462	7,567	5,265	3,491	3,626	10,418	11,423	10,361	4,306	3,728	6,791	93,836
1960	7,241	6,624	8,105	9,031	4,470	4,943	5,134	4,386	8,788	8,465	8,484	4,489	2,896	3,936	86,993
1961	4,775	5,278	6,068	8,644	6,191	5,952	3,745	4,186	10,164	15,099	7,657	3,801	3,555	3,601	88,716
1962	4,654	5,268	4,976	8,210	3,551	3,862	4,146	4,393	9,226	6,828	8,287	3,901	3,583	3,725	74,610
1963	4,658	5,604	7,048	8,082	3,769	5,275	2,092	2,844	8,301	6,940	8,276	4,616	3,475	4,173	75,153
1964	4,291	5,150	5,409	8,055	4,866	3,833	1,760	3,361	7,749	11,268	11,666	4,305	3,993	4,619	80,325
1965	5,555	5,409	7,243	10,972	7,176	6,297	2,934	4,200	10,938	7,798	7,157	4,392	3,911	3,638	87,618
1966	4,812	5,210	6,281	8,786	4,378	3,679	3,188	3,113	8,659	7,406	9,128	4,612	3,570	3,686	76,506
1967	4,587	5,197	5,755	9,493	8,467	5,192	3,491	3,639	7,044	11,877	10,454	4,278	3,831	4,313	87,617
1968	4,626	5,074	6,067	8,332	5,392	5,613	1,634	3,215	6,740	8,653	10,069	4,419	4,086	5,220	79,140
1969	5,435	5,865	7,051	9,890	6,869	5,204	4,931	4,940	13,002	9,247	8,384	4,317	3,244	3,819	92,197
1970	4,562	5,651	5,581	7,278	5,303	4,097	1,857	3,777	7,180	8,354	5,732	3,230	2,803	3,194	68,598
1971	4,532	5,187	4,372	8,434	8,945	5,764	3,040	4,438	13,603	10,558	9,555	4,375	4,661	4,070	91,534
1972	4,441	4,850	6,172	8,753	8,689	8,636	5,559	3,671	12,491	13,836	11,079	4,875	4,708	4,593	102,354
1973	4,556	4,987	6,174	8,592	3,402	3,694	1,722	1,963	4,733	6,897	6,260	3,518	2,806	3,415	62,720
1974	4,332	4,100	6,710	13,375	10,101	7,010	4,237	5,279	13,218	12,979	12,898	4,381	4,722	4,884	108,225
1975	4,238	5,298	5,235	8,290	5,542	6,563	2,529	3,354	9,474	8,678	10,630	3,410	3,084	3,936	80,261
1976	4,963	6,180	8,585	10,017	7,674	4,879	4,114	4,235	11,923	6,944	11,140	5,615	5,760	8,177	100,205
1977	5,092	5,539	5,261	7,004	3,323	3,693	1,800	1,664	5,996	5,851	5,217	3,732	2,920	3,690	60,783
1978	4,270	4,787	3,806	6,819	3,602	6,875	2,811	3,992	9,621	6,609	8,426	3,989	3,516	4,069	73,192
Average	4,813	5,298	6,048	7,907	5,359	5,034	2,796	3,418	9,124	9,180	8,281	3,984	3,528	4,076	78,845
Maximum	7,241	6,624	10,238	13,846	10,101	8,636	5,559	5,749	13,761	20,100	12,903	5,615	5,760	8,177	108,225
Minimum	3,988	4,100	3,806	3,527	3,102	3,107	1,488	1,664	3,411	5,006	4,506	3,125	2,435	3,103	54,569

Water availability for diversion to an offstream storage site from the pool behind Priest Rapids Dam has been previously determined by the U.S. Bureau of Reclamation (USBR, 2004). The total flow at Grand Coulee Dam is not greatly different than that at Priest Rapids Dam. On a long-term average annual basis, the flow at Grand Coulee Dam is 91.5 percent of the total flow at Priest Rapids Dam. There are no specified additional flow targets in the 2000 BiOp between Grand Coulee Dam and Priest Rapids Dam. This means that the water availability for diversion at Grand Coulee Dam will be similar to that at Priest Rapids Dam.

Water available for diversion to Ninemile Flat Reservoir was estimated for each month (or half-month) of each year to be the same percentage of total flow available for diversion as previously determined to be available (USBR, 2004) at Priest Rapids. Based on this methodology, the total flow available for diversion to Ninemile Flat Reservoir from Franklin D. Roosevelt Lake for each period over a 50-year period is presented in Table 5-3. The long-term average annual water availability is about 20,300,000 acre-feet, which represents about 25 percent of the total Columbia River flow at Chief Joseph Dam. The water availability would be the same for a diversion point anywhere on Franklin D. Roosevelt Lake. The variability of water availability also is large, ranging from about 1.7 million to about 59 million acre-feet per year. In some years, water is available for diversion in only the months of September and October. A reliable irrigation or municipal water supply based on the water availability in Table 5-4 would require the addition of an off-channel storage reservoir.

Table 5-4. Total Water Availability in Franklin D. Roosevelt Lake (1000's of acre-feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	1,262	0	0	1,228	0	0	0	0	0	0	0	0	0	605	3,095
1930	1,712	0	0	0	348	0	0	0	0	0	0	0	0	779	2,839
1931	1,509	0	0	0	0	0	0	0	0	0	0	0	0	1,048	2,557
1932	1,601	0	0	0	0	2,021	577	930	2,344	209	200	0	0	758	8,638
1933	1,383	0	1,435	5,034	3,173	0	0	0	0	4,777	4,459	0	0	1,335	21,595
1934	2,642	2,343	9,223	12,916	7,212	4,416	2,552	748	644	0	0	0	0	693	43,389
1935	1,446	0	899	4,391	4,523	0	0	0	0	0	24	0	0	826	12,108
1936	1,565	0	0	0	0	116	0	0	3,610	0	0	0	0	419	5,710
1937	1,574	0	0	0	0	0	0	0	0	0	0	0	0	503	2,077
1938	1,725	0	772	5,791	872	3,367	56	0	3,325	0	0	0	0	836	16,743
1939	1,394	0	0	1,821	0	328	0	0	0	0	0	0	0	487	4,031
1940	1,725	0	303	961	170	3,283	0	0	0	0	0	0	0	370	6,812
1941	1,384	0	968	2,019	0	0	0	0	0	0	0	0	0	609	4,979
1942	1,181	0	3,492	5,427	237	0	0	0	0	158	453	0	0	551	11,499
1943	1,498	0	1,269	4,711	3,447	3,785	1,696	518	3,157	1,183	1,683	0	0	462	23,410
1944	1,335	0	82	1,656	0	0	0	0	0	0	0	0	0	688	3,761
1945	1,372	0	0	0	0	0	0	0	0	0	0	0	0	290	1,662
1946	1,559	0	214	2,936	2,038	4,004	457	37	3,943	0	757	0	0	827	16,771
1947	952	0	4,879	5,457	3,962	4,102	0	0	2,012	0	218	0	0	684	22,266
1948	3,803	1,556	2,715	5,851	1,118	1,912	77	0	3,954	13,273	2,260	0	0	1,674	38,193
1949	1,599	0	888	2,178	1,417	6,103	0	624	3,028	0	0	0	0	183	16,020
1950	1,366	0	137	2,954	4,791	7,122	701	259	1,552	6,558	3,105	0	0	1,032	29,577
1951	2,088	2,365	5,951	8,538	8,315	4,646	886	935	5,534	0	1,456	0	0	1,279	41,993
1952	2,907	374	3,133	4,776	3,014	2,762	367	189	4,903	0	0	0	0	475	22,900
1953	1,322	0	0	2,723	4,467	165	0	0	493	3,490	1,717	0	0	807	15,183
1954	1,582	75	2,200	3,901	4,560	2,378	628	0	2,955	5,622	3,346	863	0	4,094	32,203
1955	2,199	1,053	1,880	978	0	0	0	0	0	6,265	5,256	0	0	896	18,526
1956	2,072	1,736	6,043	9,663	3,058	6,267	1,315	2,044	6,755	6,019	2,282	0	0	777	48,029
1957	1,566	0	2,453	3,403	0	2,283	1,192	0	3,262	4,950	0	0	0	486	19,595
1958	1,295	0	379	3,068	3,777	2,640	0	0	2,677	1,730	0	0	0	624	16,190
1959	1,284	941	3,471	8,383	4,740	2,351	1,065	0	1,205	4,172	2,805	0	0	3,729	34,145
1960	4,209	2,748	4,313	4,314	1,233	1,966	2,490	176	0	387	323	0	0	803	22,961
1961	1,549	529	925	3,866	4,715	3,682	1,242	0	352	7,175	0	0	0	378	24,414
1962	1,363	0	58	3,696	0	0	1,464	592	0	0	0	0	0	508	7,682
1963	1,488	994	3,487	3,724	2,299	1,129	0	0	0	0	37	0	0	981	14,139
1964	1,151	0	344	3,531	623	0	0	0	0	4,808	4,067	0	0	1,553	16,078
1965	2,488	153	7,063	10,612	8,000	4,756	301	566	3,437	1,491	213	0	0	616	39,697
1966	1,531	205	1,861	4,667	0	83	614	0	0	0	623	0	0	562	10,148
1967	1,305	0	1,124	5,535	5,768	592	815	0	0	5,543	3,080	0	0	1,163	24,924
1968	1,481	197	1,860	4,615	3,814	2,196	0	0	0	711	2,332	0	0	2,149	19,355
1969	2,301	1,450	2,748	7,771	4,482	3,034	2,337	1,051	5,677	534	172	0	0	607	32,164
1970	1,372	0	500	5,286	3,523	473	0	0	0	1,656	0	0	0	0	12,809
1971	1,176	0	439	7,562	9,170	4,019	544	440	6,232	4,031	2,919	0	0	793	37,325
1972	1,133	100	2,010	6,786	7,962	12,989	3,038	0	5,472	7,876	4,107	485	0	1,390	53,349
1973	1,429	0	2,512	5,419	0	0	0	0	0	0	0	0	0	0	9,360
1974	1,203	0	4,565	13,888	8,982	6,374	1,847	1,419	5,629	6,521	6,676	120	0	1,544	58,768
1975	1,076	0	777	4,981	2,450	3,936	0	0	1,997	2,206	4,622	0	0	774	22,817
1976	1,778	2,034	7,778	8,440	4,883	3,144	1,561	317	4,402	87	3,454	1,364	0	4,982	44,224
1977	1,738	0	308	1,869	0	0	0	0	0	0	0	0	0	429	4,345
1978	927	0	2,013	3,669	1,265	4,488	422	0	1,410	0	1,026	0	0	871	16,090
Average	1,652	377	1,949	4,420	2,688	2,338	565	217	1,799	2,029	1,273	57	0	979	20,343
Maximum	4,209	2,748	9,223	13,888	9,170	12,989	3,038	2,044	6,755	13,273	6,676	1,364	0	4,982	58,768
Miniumum	927	0	0	0	0	0	0	0	0	0	0	0	0	0	1,662
# Years of Avail. Water	50	17	41	44	35	35	25	16	27	26	29	4	0	48	50

5.2.2.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Ninemile Flat Dam and Reservoir is shown in Table 5-5.

Table 5-5. Pre-Appraisal-Level Cost Estimate ForNinemile Flat Dam And Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	$ 449,000,000	
2. Spillway	$ 50,000,000	
3. Pumping Plant, Pumps & Motors	$ 193,000,000	
4. Waterway (tunnel)	$ 22,000,000	
Sub-Total (Field Costs)	$ 714,000,000	
Allowances		
Mobilization (5% x Field Costs)	$ 35,700,000	
Sub-Total (Field Costs plus Mobilizaton)	$ 749,700,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	$ 112,455,000	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	$ 862,155,000	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	$ 215,538,750	
Direct Construction Costs	$ 1,077,693,750	
Indirect Costs (20% to 35% of Direct Construction Costs)	$ 215,538,750	$ 377,192,813
Range Totals	**$ 1,293,232,500**	**$1,454,886,563**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.2.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Ninemile Flat Reservoir could be used to supplement Columbia River instream flows for anadromous fish and could be released during April through August when 2000 BiOp target flows are not met at McNary Dam. The Ninemile Flat Reservoir would store enough water to meet a range of 10 to 30 percent of the 2000 BiOp target flows at McNary Dam during a one-month period from April through August based on monthly average flows at Grand Coulee, Priest Rapids and Bonneville dams.

Agricultural Irrigation

Existing Columbia Basin Project irrigation infrastructure has the potential to convey irrigation water from a potential off-stream surface storage site to agricultural land in Grant, Adams and Franklin counties. Water from the Ninemile Flat reservoir could be conveyed by existing Columbia Basin Project facilities to over 300,000 acres in Grant, Adams and Franklin Counties. Additionally, parts of Douglas (21,199 irrigated acres – IA) and Lincoln (47,984 IA) Counties lie within an arbitrary direct conveyance limit of 50 miles from the reservoir. The Ninemile Flat site could be a resource for significant agricultural irrigation in a five-county area.

M&I Water Supply

There could be potential future benefits from using Ninemile Flat storage water for an M&I water supply. The major population center within a 50-mile radius of the site would be Spokane; local water supplies are expected to be sufficient to continue meeting near term M&I water supply needs, but the Ninemile Flat Reservoir could be a resource to meet M&I water supplies for expected community growth.

Recreation

There would be some opportunities for recreational boating on the potential Ninemile Flat reservoir. Development of a fishing resource would require fish stocking and fisheries management in the potential reservoir.

5.2.2.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.2.8 Regional and Local Geology

The Ninemile Flat site is located on Ninemile Creek at the north edge of the Columbia Plateau, a structural and topographic basin, which encompasses most of the Columbia River drainage. Most of the Columbia Plateau is underlain by Miocene basalts of the Columbia River Basalt Group, although bedrock exposed at this site and others along the north edge of the Columbia Plateau consist of Precambrian to lower Tertiary rocks of the Okanogan Highlands (Drost and Whiteman, 1986; Drost et al., 1990; Swanson et al., 1979). At the Ninemile Flat site and vicinity, the exposed bedrock consists of pre-Tertiary metasedimentary rocks and Paleozoic marine sediments. Northeast of the site, Tertiary granitic outcrops are exposed at higher elevations. Most of the local area is covered by 50 feet or more of Quaternary alluvial sediments; no detailed description of soils was identified. A north-south trending fault is located approximately 15 miles northwest of the site. No other major structural features have been identified at this location (Drost and Whiteman, 1986; Schuster, 1992).

5.2.2.9 Potential Environmental and Institutional Issues

There would be no direct long-term impacts on anadromous fish populations from construction and operation of a dam and reservoir at this site. The dam would be located approximately one mile upstream of Ninemile Falls, which appears to be a natural barrier to anadromous fish passage.

There are no major utilities or structures in the Ninemile Flat potential reservoir area. Dirt roads are located in the potential reservoir, but there are no major traffic routes through the area of potential inundation. The area within the potential reservoir site is cropped. There are no wildlife refuges designated in the potential reservoir area.

The dam and reservoir site would be located entirely within the Colville Indian Reservation boundaries, and the Colville Confederated Tribes would have to be consulted concerning potentially sensitive sites with respect to natural resources, cultural resources and other trust resources within the potential project boundary. The reservoir would inundate approximately 326 acres of National Wetland Inventory (NWI) wetlands at full pool elevation.

The Washington State GAP Analysis database (WAGAP, 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with predicted habitat or recorded occurrences in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. Habitat in the Ninemile Flat reservoir site is almost completely covered in conifer forest with ponderosa pine predominant with areas of Douglas fir and lodgepole pine/western larch. There are a few small areas of cropland and pasture. Table 5-6 summarizes listed vertebrate species that have potential habitat in the area of the Ninemile Flat dam and reservoir site.

Table 5-6. Listed Vertebrate Species With GAP Habitat at the Ninemile Flat Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Columbia spotted frog	*Rana lutreiventris*	NL	SC
Western toad	*Bufo borealis*	NL	SC
Black-backed woodpecker	*Picoides arcticus*	NL	SC
Flammulated owl	*Otus flammeolus*	NL	SC
Golden eagle	*Aquila chryseatos*	NL	SC
Pileated woodpecker	*Dryocopus pileatus*	NL	SC
Vaux's swift	*Chaetura vauxi*	NL	SC
White-headed woodpecker	*Picoides albolarvatus*	NL	SC
Black-tailed jack rabbit	*Lepus californicus*	NL	SC
Fisher	*Martes pennanti*	NL	SE
Merriam's shrew	*Sorex merriami*	NL	SC
Townsend's big-eared bat	*Coryhorhinus townsendii*	NL	SC

Notes:
[1] NL = Not Listed
[2] SC = State Candidate; SE = State Endangered

Small animals with limited dispersal capacity and home ranges impacted by dam construction or inundated by the reservoir would be at greatest risk. Large mobile species and birds could disperse from the construction and inundation zones. Bats would generally not be impacted unless a dam or reservoir would cover or inundate a hibernaculum. The listed species have potential habitat in the reservoir area, but no observations have been recorded.

5.2.2.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Ninemile Flat site would involve the following environmental and institutional issues of concern:

- Approximately 326 acres of NWI wetlands would be impacted, requiring a Clean Water Act Section 404 permit and mitigation.
- The site is located within the boundaries of the Colville Indian Reservation and the Colville Confederated Tribes would have to be consulted concerning potentially sensitive sites with respect to natural resources, cultural resources and other trust resources within the potential project boundary.
- Potential impacts on Indian Trust Assets must be considered, evaluated, analyzed and mitigated.

5.2.3 Hawk Creek Dam and Reservoir Site

5.2.3.1 Site Location

The Hawk Creek site is located south of the Columbia River, approximately 40 river miles upstream of Grand Coulee Dam. The dam and reservoir would be located in north Lincoln County in Townships 25 and 26 North, Range 36 East on the USGS 1:100,000 scale Coulee Dam, Washington topographic quadrangle (see Site 3 on Map 1). Map 4 shows the potential Hawk Creek Dam and Reservoir location in Lincoln County.

5.2.3.2 Previous Investigations

None identified.

5.2.3.3 Current Analysis

The Hawk Creek dam and reservoir site would have a full-pool elevation at 2,000 feet MSL and would inundate portions of Hawk Creek, Indian Creek, Snook Canyon and Stock Creek (see Map 5). Figure 5-9 shows the elevation-capacity-area curves for the potential Hawk Creek reservoir. Figure 5-10 shows a cross-section of the proposed dam site looking downstream.

Reservoir Volume

Total potential storage volume is estimated at approximately 1,550,000 acre-feet. Usable storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 1,400,000 acre-feet.

Inundated Area

The inundated surface area at full-pool elevation would be approximately 7,070 acres.

Dam Size

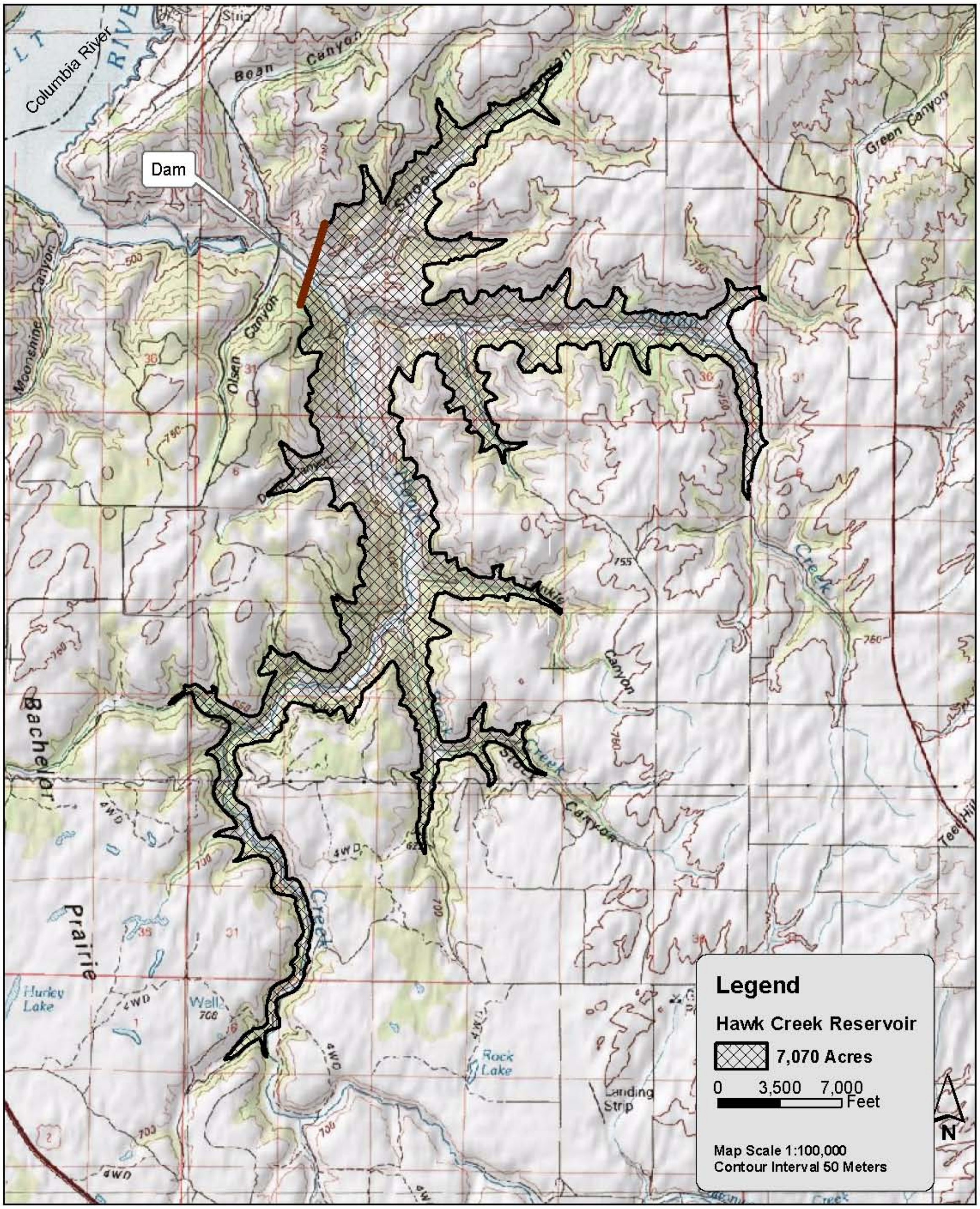
The dam would be approximately 4,900 feet long by 610 feet high, including a 10-foot freeboard.

5.2.3.4 Water Sources and Availability

No flow data is available for Hawk Creek. In comparison to the flow pumped from the Columbia River, natural inflows at the dam site would be negligible. The diversion point would be in Franklin D.

Roosevelt Lake. Water availability would be the same as presented in section 5.2.2.4 for Ninemile Flat Dam and Reservoir.

Map 4
Hawk Creek Dam and Reservoir Location Map



Map 5
Hawk Creek Dam and Reservoir Site Map

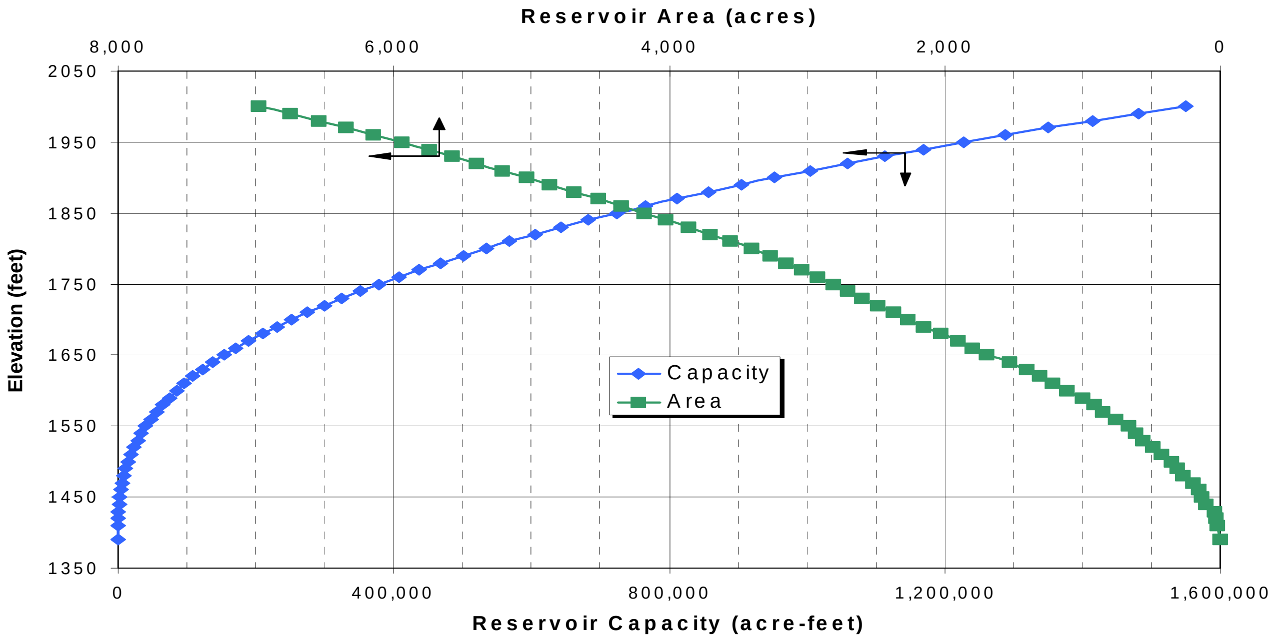


Figure 5-9. Hawk Creek Reservoir Elevation-Capacity-Area Curves

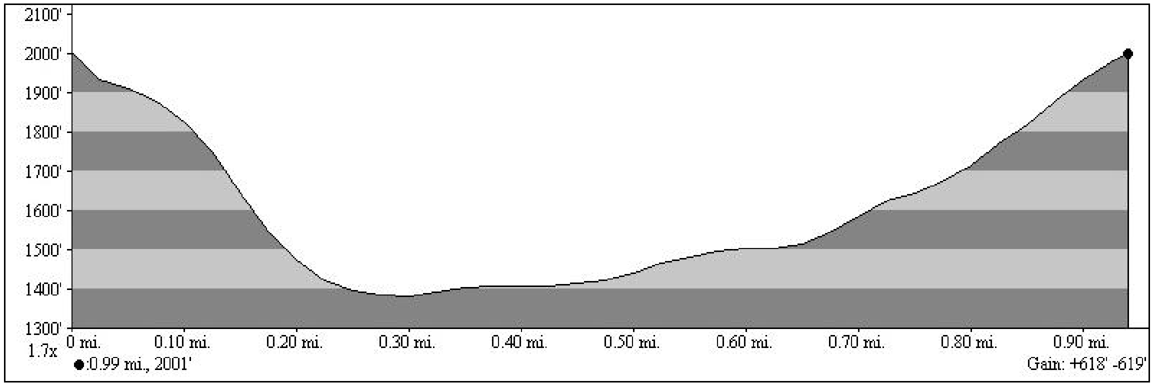


Figure 5-10. Hawk Creek Dam Cross Section

5.2.3.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Hawk Creek Dam and Reservoir is shown in Table 5-7.

Table 5-7. Pre-Appraisal-Level Cost Estimate forHawk Creek Dam and Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	$ 498,000,000	
2. Spillway/Outlet Works	$ 50,000,000	
3. Pumping Plant, Pumps & Motors	$ 217,000,000	
4. Waterway (tunnel)	$ 32,000,000	
Sub-Total (Field Costs)	$ 797,000,000	
Allowances		
Mobilization (5% x Field Costs)	$ 39,850,000	
Sub-Total (Field Costs plus Mobilizaton)	$ 836,850,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	$ 125,527,500	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	$ 962,377,500	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	$ 240,594,375	
Direct Construction Costs	$ 1,202,971,875	
Indirect Costs (20% to 35% of Direct Construction Costs)	$ 240,594,375	$ 421,040,156
Range Totals	**$ 1,443,566,250**	**$ 1,624,012,031**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.3.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Hawk Creek Reservoir could be used to supplement Columbia River instream flows for anadromous fish and could be released during April through August when 2000 BiOp target flows are not met at McNary Dam. The Hawk Creek Reservoir would store enough water to meet a range of 15 to 46 percent of the 2000 BiOp target flows at McNary Dam during a one-month period from April through August based on monthly average flows at Grand Coulee, Priest Rapids and Bonneville dams.

Agricultural Irrigation

Existing Columbia Basin Project irrigation infrastructure has the potential to convey irrigation water from a potential off-stream surface storage site to agricultural land in Grant, Adams and Franklin counties. Water from the Ninemile Flat reservoir could be conveyed by existing Columbia Basin Project facilities to over 300,000 acres in Grant, Adams and Franklin Counties. Additionally, most of Douglas (21,199 irrigated acres - IA), and western Lincoln (47,984 IA) Counties lie within an arbitrary direct conveyance limit of 50 miles. The Hawk Creek site could be a potential resource for agricultural irrigation in a five-county area.

M&I Water Supply

There could be potential future benefits from using Hawk Creek storage water for an M&I water supply. The major population center within a 50-mile radius of the site would be Spokane; local water supplies are expected to be sufficient to continue meeting near term M&I water supply needs, but the Hawk Creek Reservoir could be a resource to meet M&I water supplies for expected community growth.

Recreation

There would be some opportunities for recreational boating on the potential Hawk Creek reservoir. Development of a fishing resource would require fish stocking and fisheries management in the potential reservoir.

5.2.3.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.3.8 Regional and Local Geology

The Hawk Creek site is located on Hawk Creek near the north edge of the Columbia Plateau, a structural and topographic basin, which encompasses most of the Columbia River drainage. Exposed rock in the canyon walls at this site is the Grande Ronde Basalt, a lower Miocene unit of the Columbia River Basalt Group consisting of multiple flows with rare sedimentary interbeds. The Grande Ronde Basalt is probably less than 200 feet thick at this location and may be weathered at the top of the highest flow. Overlying the Grande Ronde Basalt in the downcut canyon walls is the middle to upper Miocene Wanapum Basalt, which is probably only a few hundred feet thick in this vicinity but is widely exposed at the surface to the south, east, and west (Drost and Whiteman, 1986). Exposed rock outcrops are not extensively weathered. Contacts between individual flows in both the Grande Ronde and Wanapum basalts are sometimes rubbly and fractured, and these contact zones tend to be zones of higher permeability. The contact between the Grande Ronde and Wanapum basalts often is divided by either the Vantage Member of the Ellensburg Formation (typically expressed as a siltstone or tuffaceous conglomerate) or a clay-rich, soft saprolite (Swanson et al., 1979). If present at this location, the interbed is probably no more than a few feet thick. Alluvial sediments of unknown thickness cover the valley floor. Sediments described in the vicinity range from silt and clay to sand, gravel, and well-graded mixtures (NRCS, 1981). No major structural features have been identified at this location (Drost and Whiteman, 1986).

5.2.3.9 Potential Environmental and Institutional Issues

There would be no direct long-term impacts on anadromous fish populations from construction and operation of a dam and reservoir at this site. The proposed dam site would be approximately 0.8 miles upstream from a 30-foot high natural falls that is an absolute barrier to anadromous fish passage.

There are no major utilities or structures in the Hawk Creek or Indian Creek drainages. Dirt roads are located in the Hawk Creek and Indian Creek canyons, but there are no major traffic routes through the area of potential inundation. The area around the potential reservoir site is extensively cropped, but there is no significant agricultural development in the reservoir area proper. There are no wildlife refuges designated in the potential reservoir area. The reservoir would inundate approximately 50 acres of NWI wetlands at full pool elevation.

The Washington State GAP Analysis database (WAGAP, 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with predicted habitat or recorded occurrences in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. The Hawk Creek reservoir site is a mixed riparian community at the base of the down-cut Hawk Creek drainage and its major tributaries, surrounded by open ponderosa pine forest on the slopes. The top land is comprised of interspersed grasslands and dryland agriculture (winter wheat). Table 5-8 summarizes listed vertebrate species that have potential habitat in the area of the potential Hawk Creek dam and reservoir site.

Table 5-8. Listed Vertebrate Species With GAP Habitat in the Hawk Creek Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Columbia spotted frog	*Rana lutreiventris*	NL	SC
Western toad	*Bufo borealis*	NL	SC
Black-backed woodpecker	*Picoides arcticus*	NL	SC
Flammulated owl	*Otus flammeolus*	NL	SC
Golden eagle	*Aquila chryseatos*	NL	SC
Lewis' woodpecker	*Melanerpes lewis*	NL	SC
Loggerhead shrike	*Lanius ludovicianus*	NL	SC
Pileated woodpecker	*Dryocopus pileatus*	NL	SC
Sage grouse	*Centrocercus urophasianus*	NL	SC
Sage thrasher	*Oreoscoptes montanus*	NL	SC
Sharp-tailed grouse	*Tympanuchus phasianellus*	NL	ST
White-headed woodpecker	*Picoides albolarvatus*	NL	SC
Black-tailed jack rabbit	*Lepus californicus*	NL	SC
Merriam's shrew	*Sorex merriami*	NL	SC
Townsend's big-eared bat	*Coryhorhinus townsendii*	NL	SC
White-tailed jack rabbit	*Lepus townsendii*	NL	SC

Notes:
[1] NL = Not Listed
[2] SC = State Candidate; ST = State Threatened

Small animals with limited dispersal capacity and home ranges impacted by dam construction or inundated by the reservoir would be at greatest risk. Large mobile species and birds could disperse from the construction and inundation zones. Bats would generally not be impacted unless a dam or reservoir would cover or inundate a hibernaculum. The listed species have potential habitat in the reservoir area, but no observations have been recorded.

One listed plant species is located near the Hawk Creek site by the Washington Natural Heritage Program (WNHP 2005) – the least bladery milkvetch (*Astralagus microcystis*). The map scale does not allow for specific inclusion/exclusion at the site; if the site is considered for development, a specific survey for the species should be performed.

5.2.3.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Hawk Creek site would involve the following environmental and institutional issues of concern:

- Approximately 50 acres of NWI wetlands would be impacted

5.2.4 Barker Canyon Dam and Reservoir Site

The Barker Canyon Dam and Reservoir site is located west of the Columbia River on the border between Douglas and Grant Counties (see Site 4 on Map 1). Potential reservoir volume at the highest practical full-pool elevation is not consistent with the minimum active storage assumption and the site was not evaluated in detail.

5.2.5 Goose Lake Dam and Reservoir Site

5.2.5.1 Site Location

The Goose Lake dam and reservoir site lies in a basin north of the Columbia River, between Rufus Woods Lake (Chief Joseph Reservoir) and Omak Lake within the boundaries of the Colville Indian Reservation. The dam and reservoir would be located in south Okanogan County in Townships 30 and 31 North, Range 27 East in the USGS 1:100,000 scale Omak Lake, Washington topographic quadrangle (see Site 5 on Map 1). Some dry land farming occurs in the potential project area, with the remainder covered by natural semi-arid vegetation. Map 6 shows the potential Goose Lake dam and reservoir location in Okanogan County.

5.2.5.2 Previous Investigations

Corps of Engineers

1962 Report. The site was initially proposed in a Corps of Engineers report to Congress entitled “Water Resource Development, Columbia River Basin, June, 1958.” The report was published in final form in 1962 in House Document 403, 87th Congress, 2nd Session. The original proposal would have created a 21-mile long upper reservoir by building a dam 180 feet high by 8,500 feet long south of Goose Lake. The upper reservoir in that configuration would have inundated all of Goose Lake and Omak Lake and would have provided about 1,800,000 acre-feet of usable storage between elevations 1,240 feet and 1,360 feet. At that time the project was found to have a benefit-cost ratio of less than unity and was eliminated from further consideration.

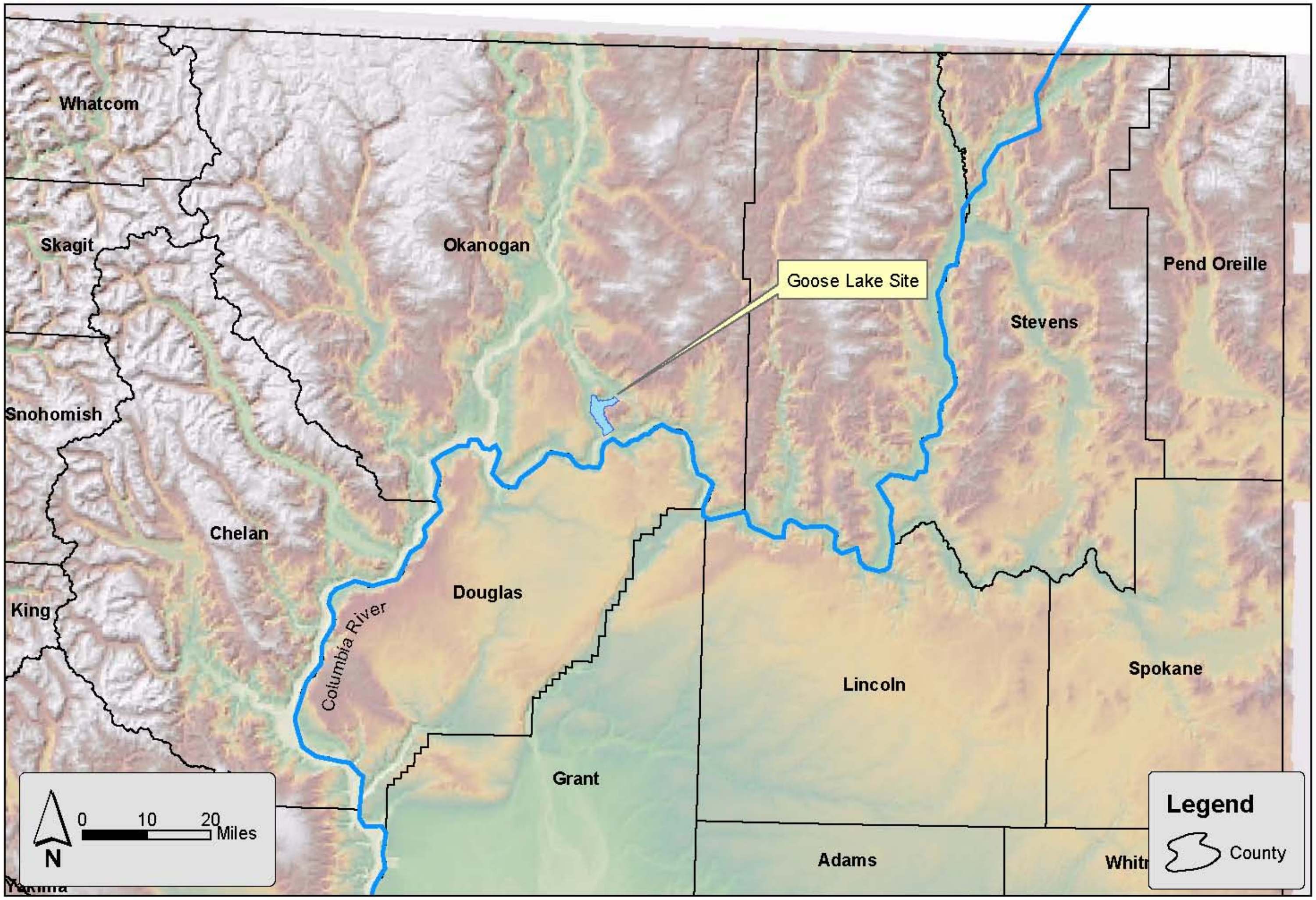
1976 Report. A subsequent Corps of Engineers report entitled "Pumped-Storage in the Pacific Northwest, an Inventory" (North Pacific Division, Portland OR, Report No. 26, January 1976) had a different configuration (named "Goose Flats Site") with the full pool elevation at 1,400 feet MSL and three small dikes confining the upper (northern) extremities of the reservoir so that Omak Lake would not be inundated. The storage volume was estimated at 700,000 acre-feet. Power generation benefits versus costs were estimated to be 1:5 in the report.

5.2.5.3 Current Analysis

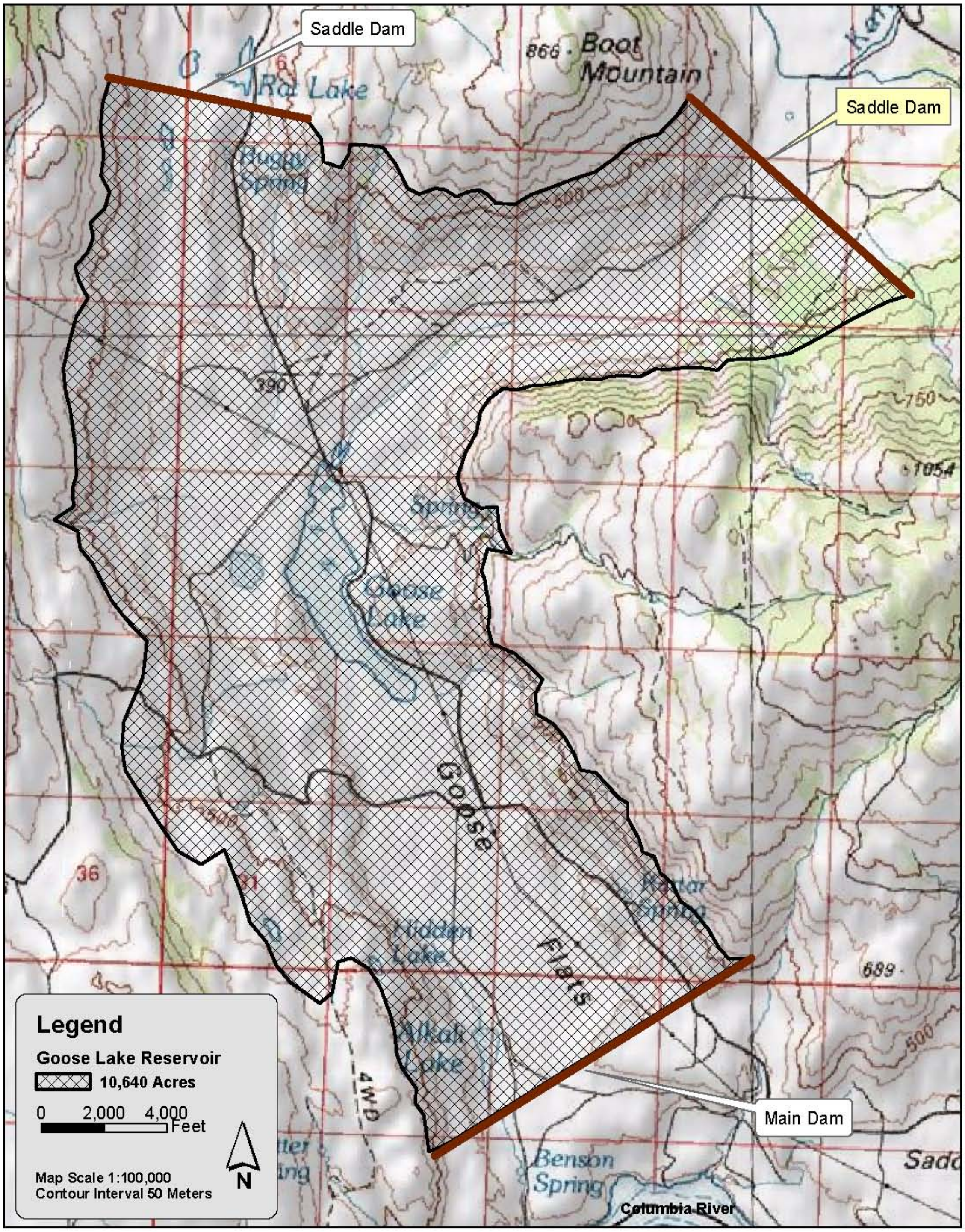
The current Goose Lake dam and reservoir site would exceed the 1976 Corps of Engineers study configuration with the full-pool elevation at 1,750 feet MSL (see Map 7). Figure 5-11 shows the elevation-capacity-area curve for the potential Goose Lake reservoir. Figure 5-12 shows a cross-section of the proposed dam site looking downstream.

Reservoir Volume

Total potential storage volume is estimated at approximately 3,720,000 acre-feet. Usable storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 3,350,000 acre-feet.



Map 6
Goose Lake Dam and Reservoir Location Map



Map 7
Goose Lake Dam and Reservoir Site Map

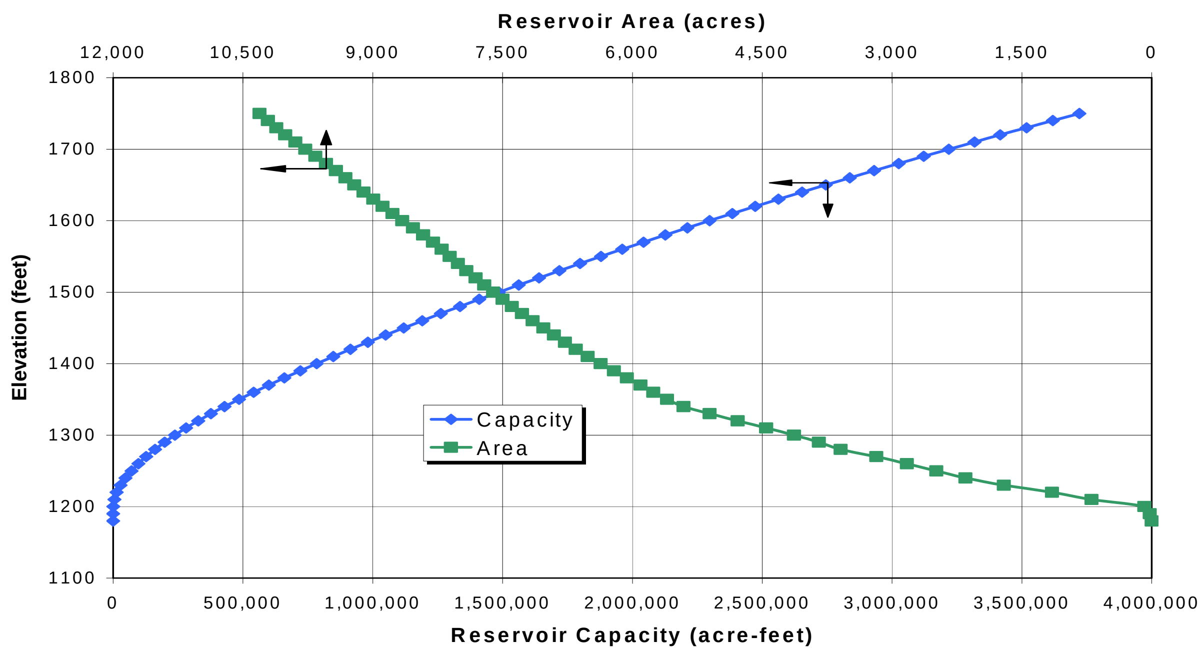


Figure 5-11. Goose Lake Reservoir Elevation-Capacity-Area Curves

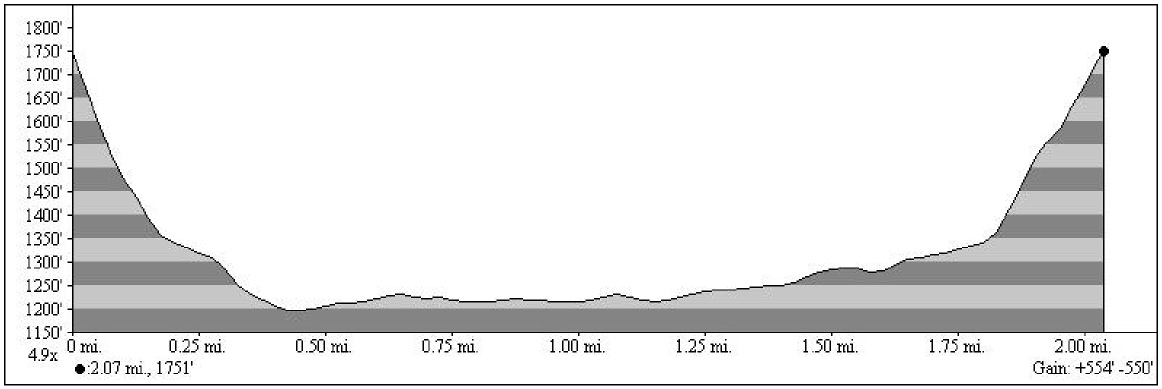


Figure 5-12. Goose Lake Dam Cross Section

Inundated Area

The inundated surface area at full-pool elevation would be approximately 10,640 acres.

Dam Size

The main dam would be approximately 11,800 feet long by 550 feet high, including a 10-foot freeboard. There would be two large confining saddle dams totaling 16,800 feet long at the north and northeast ends of the reservoir to prevent inundation into the Omak Lake area. (see Map 7).

5.2.5.4 Water Sources and Availability

No flow data is available for the Goose Lake site. A perennial stream does not even exist at the site. In comparison to the flow pumped from the Columbia River, natural inflows at the dam site would be negligible. The diversion point would be in Rufus Woods Lake, which is impounded by Chief Joseph Dam.

Table 5-9 shows the total outflow in thousands of acre-feet at Chief Joseph Dam for the simulated 50-year period. The data in Table 5-9 were developed from HYDROSIM output for the Columbia River simulation of conditions under the 2000 BiOp. The long-term average annual flow is 78,800,000 acre-feet, which ranges from annual flows of about 55,000,000 acre-feet to 106,000,000 acre-feet. Flow typically peaks during the months of May, June, and July, but winter peak flows during floods can also occur.

Water availability for diversion to an offstream storage site from the pool behind Priest Rapids Dam has been previously determined by the U.S. Bureau of Reclamation (USBR, 2004). The total flow at Chief Joseph Dam is not greatly different than that at Priest Rapids Dam. On a long-term average annual basis, the flow at Chief Joseph Dam is 91.5 percent of the total flow at Priest Rapids Dam. On an average monthly basis, total flow at Chief Joseph Dam ranges from a high of about 96 percent in January to a low of about 84 percent in June in comparison to the flow at Priest Rapids Dam. There are no specified additional flow targets in the 2000 BiOp between Chief Joseph Dam and Priest Rapids Dam. This means that the water availability for diversion at Chief Joseph Dam will be similar to that at Priest Rapids Dam.

Water available for diversion to Goose Lake Reservoir was estimated for each month (or half-month) of each year to be the same percentage of total flow available for diversion as previously determined to be available (USBR, 2004) at Priest Rapids. For example, in June 1953, 32.9 percent of the total outflow at Priest Rapids Dam was determined to be available for diversion. In June 1953, the same 32.9 percent of total outflow as simulated at Chief Joseph Dam would be available for diversion. Based on this methodology, the total flow available for diversion to Goose Lake Reservoir from Rufus Woods Lake for each period over a 50-year period is presented in Table 5-10. The water availability in Rufus Woods Lake shows little change from the water availability in Franklin D. Roosevelt Lake because there is no significant difference in the total outflow or target flow releases between Chief Joseph Dam and Grand Coulee Dam. The long-term average annual water availability is about 20,300,000 acre-feet, which represents about 25 percent of the total Columbia River flow at Chief Joseph Dam.

Table 5-9. Total Columbia River Flow at Chief Joseph Dam (1000's of acre-feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	4,339	5,358	5,352	6,325	3,389	3,742	1,899	1,832	3,506	5,005	6,114	3,153	2,960	3,697	56,673
1930	4,852	5,794	5,388	3,977	3,627	3,990	1,902	1,833	3,411	6,685	6,813	3,574	3,283	3,837	58,963
1931	4,726	5,696	5,944	3,786	3,387	3,806	1,869	1,784	4,510	7,095	5,996	3,643	3,264	4,180	59,686
1932	4,851	5,463	5,833	3,723	3,339	3,552	3,239	5,069	9,985	9,134	7,764	4,296	3,918	3,852	74,018
1933	4,607	4,557	6,417	9,365	7,669	3,614	2,322	3,062	9,020	11,644	12,162	4,178	4,739	4,350	87,705
1934	5,768	6,621	10,238	13,846	9,881	7,088	5,147	5,299	11,668	6,449	8,327	3,216	2,771	3,802	100,121
1935	4,615	4,660	5,792	9,081	8,372	3,268	2,370	3,380	7,978	7,824	8,416	4,323	3,161	3,902	77,142
1936	4,739	5,513	5,881	4,285	3,411	3,770	1,830	2,122	11,598	7,816	6,750	3,911	3,051	3,537	68,212
1937	4,778	5,689	5,777	4,333	3,679	4,045	1,970	1,985	3,861	5,128	6,056	3,626	2,841	3,610	57,379
1938	4,916	5,136	4,745	9,762	4,747	5,600	2,666	3,526	11,494	7,459	7,409	3,124	2,546	4,018	77,148
1939	4,559	5,303	4,963	6,766	3,512	3,780	1,770	2,341	9,099	6,804	6,590	4,027	3,153	3,620	66,287
1940	4,946	5,377	5,623	5,955	3,874	5,590	2,197	3,182	6,800	7,760	6,020	3,358	2,933	3,552	67,167
1941	4,567	4,823	5,812	6,590	3,102	3,949	1,520	2,000	5,503	6,664	4,950	3,126	2,976	3,736	59,317
1942	4,221	4,396	6,878	9,500	3,548	3,107	1,487	2,259	6,304	9,292	8,995	4,399	3,663	3,631	71,680
1943	4,602	4,742	4,857	7,261	4,864	5,113	4,241	4,028	11,688	8,187	7,509	3,900	3,462	3,412	77,867
1944	4,431	5,228	4,736	6,779	3,258	3,616	1,765	1,727	3,743	5,218	4,505	3,185	2,617	3,757	54,565
1945	4,545	5,428	5,672	3,527	3,197	3,618	1,733	1,720	5,637	7,674	6,411	3,232	3,112	3,302	58,810
1946	4,679	5,100	4,349	5,857	5,391	5,904	3,078	4,175	12,276	8,918	8,385	4,328	3,537	3,820	79,796
1947	3,988	4,734	6,901	8,913	5,863	7,170	2,280	3,853	9,650	8,427	8,308	4,334	3,033	3,723	81,177
1948	7,024	5,872	6,804	8,443	3,945	5,094	2,780	4,224	11,687	20,099	9,129	4,126	4,637	4,517	98,380
1949	4,579	4,849	5,598	6,991	4,390	6,401	1,897	4,675	9,562	7,807	5,422	3,128	2,434	3,103	70,837
1950	4,467	4,871	4,413	7,558	7,128	7,859	3,257	4,158	10,353	13,264	8,921	3,662	4,099	3,942	87,953
1951	5,168	5,808	8,094	10,625	8,717	6,041	3,259	4,774	13,546	6,932	9,586	4,151	4,146	4,235	95,081
1952	6,053	5,114	6,682	8,853	5,255	5,940	3,066	3,788	12,614	7,874	7,062	4,119	2,958	3,683	83,063
1953	4,627	5,667	5,479	5,185	6,348	3,719	1,798	2,711	9,519	10,663	9,006	4,206	3,454	3,951	76,332
1954	4,760	5,201	6,468	7,742	6,947	6,053	3,235	2,949	11,610	14,634	10,780	5,202	4,629	7,152	97,361
1955	5,375	5,898	6,958	5,768	3,680	3,861	1,842	1,827	5,968	14,312	13,143	4,094	4,562	3,911	81,198
1956	5,222	5,710	7,644	11,014	5,479	6,774	3,781	5,608	13,841	12,143	9,675	4,188	3,865	3,804	98,749
1957	4,682	4,818	6,081	8,203	3,643	3,997	3,722	3,350	9,995	11,993	7,122	3,398	2,812	3,605	77,420
1958	4,495	5,291	4,781	7,101	5,415	5,869	1,948	3,497	9,651	9,717	6,342	3,461	3,125	3,748	74,440
1959	4,400	5,231	6,728	10,459	7,590	5,272	3,467	3,626	10,413	11,290	10,459	4,262	3,762	6,797	93,756
1960	7,234	6,603	8,134	9,017	4,472	4,940	5,124	4,408	8,823	8,479	8,494	4,506	2,897	3,929	87,061
1961	4,723	5,253	6,054	8,621	6,189	5,969	3,734	4,198	10,141	15,085	7,676	3,768	3,503	3,590	88,503
1962	4,641	5,231	4,923	8,190	3,556	3,828	4,112	4,301	9,141	6,940	8,411	3,963	3,589	3,752	74,579
1963	4,654	5,575	7,082	8,128	3,786	5,263	2,069	2,800	8,327	7,101	8,257	4,572	3,474	4,186	75,274
1964	4,366	5,158	5,548	8,101	4,929	3,858	1,772	3,363	7,907	11,807	12,102	4,357	4,049	4,778	82,094
1965	5,706	5,423	7,231	10,903	7,010	6,362	2,912	4,188	10,889	8,110	7,205	4,402	3,933	3,710	87,983
1966	4,796	5,326	6,401	8,887	4,399	3,774	3,241	3,160	8,709	7,752	9,452	4,675	3,586	3,778	77,936
1967	4,628	5,257	5,717	9,576	8,605	5,290	3,493	3,663	7,242	12,477	11,374	4,522	3,992	4,383	90,220
1968	4,702	5,138	6,139	8,378	5,372	5,809	1,696	3,268	6,926	9,042	10,595	4,698	4,222	5,405	81,391
1969	5,544	5,931	7,079	9,992	7,072	5,309	4,895	4,727	12,748	9,102	8,431	4,425	3,256	3,921	92,431
1970	4,390	5,539	5,516	7,138	5,221	3,935	1,792	3,698	7,084	8,310	5,848	3,288	2,847	3,176	67,781
1971	4,337	5,147	4,195	8,250	8,616	5,288	3,010	4,394	13,360	10,286	9,261	4,417	4,665	4,060	89,286
1972	4,350	4,645	5,950	8,502	8,484	8,413	5,419	3,565	12,285	13,993	11,078	4,874	4,738	4,518	100,813
1973	4,650	4,924	5,967	8,460	3,323	3,706	1,739	1,997	4,768	6,981	6,376	3,532	2,778	3,387	62,589
1974	4,253	3,994	6,598	13,038	10,095	6,993	4,166	5,185	12,959	12,651	12,680	4,359	4,666	4,738	106,376
1975	4,287	5,235	5,052	8,054	5,331	6,362	2,466	3,304	9,365	8,676	10,579	3,252	2,946	3,827	78,736
1976	4,736	5,903	8,339	9,820	7,744	4,606	3,946	3,966	11,229	6,657	11,050	5,291	5,421	7,758	96,466
1977	4,724	5,156	4,942	7,013	3,200	3,416	1,701	1,599	5,881	5,739	5,096	3,682	2,863	3,493	58,505
1978	4,270	4,771	3,800	6,820	3,599	6,876	2,797	3,993	9,623	6,613	8,433	3,990	3,529	4,586	73,699
Average	4,812	5,283	6,031	7,889	5,353	5,024	2,788	3,403	9,078	9,194	8,330	3,990	3,529	4,095	78,800
Maximum	7,234	6,621	10,238	13,846	10,095	8,413	5,419	5,608	13,841	20,099	13,143	5,291	5,421	7,758	106,376
Minimum	3,988	3,994	3,800	3,527	3,102	3,107	1,487	1,599	3,411	5,005	4,505	3,124	2,434	3,103	54,565

Table 5-10. Total Water Availability in Rufus Woods Lake (1000's of acre-feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	1,262	0	0	1,228	0	0	0	0	0	0	0	0	0	605	3,095
1930	1,712	0	0	0	348	0	0	0	0	0	0	0	0	779	2,839
1931	1,509	0	0	0	0	0	0	0	0	0	0	0	0	1,048	2,557
1932	1,601	0	0	0	0	2,021	577	930	2,344	209	200	0	0	758	8,638
1933	1,383	0	1,435	5,034	3,173	0	0	0	0	4,776	4,458	0	0	1,335	21,594
1934	2,642	2,343	9,223	12,916	7,212	4,416	2,552	748	644	0	0	0	0	693	43,389
1935	1,446	0	899	4,391	4,523	0	0	0	0	0	24	0	0	826	12,108
1936	1,565	0	0	0	0	116	0	0	3,610	0	0	0	0	419	5,710
1937	1,574	0	0	0	0	0	0	0	0	0	0	0	0	503	2,077
1938	1,725	0	772	5,791	872	3,367	56	0	3,325	0	0	0	0	836	16,743
1939	1,394	0	0	1,821	0	328	0	0	0	0	0	0	0	487	4,031
1940	1,725	0	303	961	170	3,283	0	0	0	0	0	0	0	370	6,812
1941	1,384	0	968	2,019	0	0	0	0	0	0	0	0	0	609	4,979
1942	1,181	0	3,492	5,427	237	0	0	0	0	158	453	0	0	551	11,498
1943	1,498	0	1,269	4,711	3,447	3,785	1,696	518	3,157	1,183	1,683	0	0	462	23,409
1944	1,335	0	82	1,656	0	0	0	0	0	0	0	0	0	688	3,761
1945	1,372	0	0	0	0	0	0	0	0	0	0	0	0	290	1,662
1946	1,559	0	214	2,936	2,038	4,004	457	37	3,942	0	757	0	0	827	16,771
1947	952	0	4,879	5,457	3,962	4,102	0	0	2,012	0	218	0	0	684	22,266
1948	3,803	1,556	2,715	5,851	1,118	1,912	77	0	3,954	13,273	2,259	0	0	1,674	38,192
1949	1,599	0	888	2,178	1,417	6,103	0	624	3,028	0	0	0	0	183	16,020
1950	1,366	0	137	2,954	4,791	7,122	701	259	1,552	6,558	3,104	0	0	1,032	29,576
1951	2,088	2,365	5,951	8,538	8,315	4,646	886	935	5,534	0	1,456	0	0	1,279	41,993
1952	2,907	374	3,133	4,776	3,014	2,762	381	197	4,879	0	0	0	0	499	22,921
1953	1,370	0	0	2,801	4,566	171	0	0	492	3,505	1,725	0	0	841	15,472
1954	1,621	76	2,237	3,959	4,614	2,422	642	0	2,851	5,585	3,349	877	0	4,122	32,355
1955	2,260	1,064	1,902	980	0	0	0	0	0	6,220	5,354	0	0	941	18,722
1956	2,098	1,755	6,119	9,760	3,118	6,335	1,304	1,994	6,794	5,837	2,321	0	0	802	48,236
1957	1,582	0	2,479	3,394	0	2,366	1,188	0	3,205	4,973	0	0	0	489	19,677
1958	1,298	0	376	3,027	3,771	2,688	0	0	2,614	1,693	0	0	0	627	16,093
1959	1,284	939	3,456	8,380	4,754	2,354	1,057	0	1,205	4,124	2,832	0	0	3,732	34,117
1960	4,205	2,739	4,328	4,307	1,234	1,965	2,485	177	0	388	323	0	0	802	22,952
1961	1,532	527	923	3,855	4,713	3,692	1,239	0	352	7,168	0	0	0	377	24,379
1962	1,360	0	58	3,687	0	0	1,452	580	0	0	0	0	0	512	7,648
1963	1,486	989	3,504	3,745	2,310	1,126	0	0	0	0	37	0	0	984	14,181
1964	1,171	0	353	3,551	631	0	0	0	0	5,038	4,219	0	0	1,606	16,570
1965	2,556	154	7,051	10,546	7,815	4,805	299	565	3,422	1,551	214	0	0	628	39,605
1966	1,527	209	1,897	4,721	0	86	624	0	0	0	645	0	0	576	10,285
1967	1,316	0	1,117	5,584	5,862	603	815	0	0	5,823	3,351	0	0	1,182	25,654
1968	1,506	200	1,882	4,640	3,799	2,273	0	0	0	743	2,453	0	0	2,226	19,722
1969	2,348	1,466	2,759	7,851	4,614	3,095	2,320	1,006	5,566	525	173	0	0	624	32,347
1970	1,320	0	494	5,184	3,469	454	0	0	0	1,647	0	0	0	0	12,568
1971	1,125	0	421	7,396	8,833	3,687	538	435	6,120	3,928	2,829	0	0	791	36,106
1972	1,109	96	1,937	6,591	7,774	12,654	2,962	0	5,382	7,965	4,106	485	0	1,368	52,431
1973	1,458	0	2,428	5,336	0	0	0	0	0	0	0	0	0	0	9,222
1974	1,181	0	4,489	13,539	8,977	6,359	1,816	1,394	5,519	6,356	6,564	119	0	1,498	57,810
1975	1,088	0	750	4,839	2,357	3,815	0	0	1,974	2,205	4,600	0	0	752	22,379
1976	1,697	1,942	7,555	8,274	4,928	2,969	1,497	297	4,145	83	3,426	1,285	0	4,726	42,826
1977	1,613	0	289	1,872	0	0	0	0	0	0	0	0	0	406	4,180
1978	927	0	2,009	3,669	1,264	4,488	420	0	1,411	0	1,027	0	0	981	16,197
Average	1,652	376	1,944	4,403	2,681	2,328	561	214	1,781	2,030	1,283	55	0	981	20,288
Maximum	4,205	2,739	9,223	13,539	8,977	12,654	2,962	1,994	6,794	13,273	6,564	1,285	0	4,726	57,810
Minimum	927	0	0	0	0	0	0	0	0	0	0	0	0	0	1,662
# Years of Avail. Water	50	17	41	44	35	35	25	16	27	26	29	4	0	48	50

5.2.5.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Goose Lake Dam and Reservoir is shown in Table 5-11.

Table 5-11. Pre-Appraisal-Level Cost Estimate for Goose Lake Dam and Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	$ 1,250,000,000	
2. Spillway/Outlet Works	$ 100,000,000	
3. Pumping Plant, Pumps & Motors	$ 259,000,000	
4. Waterway (tunnel)	$ 30,000,000	
Sub-Total (Field Costs)	$ 1,639,000,000	
Allowances		
Mobilization (5% x Field Costs)	$ 81,950,000	
Sub-Total (Field Costs plus Mobilizaton)	$ 1,720,950,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	$ 258,142,500	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	$ 1,979,092,500	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	$ 494,773,125	
Direct Construction Costs	$ 2,473,865,625	
Indirect Costs (20% to 35% of Direct Construction Costs)	$ 494,773,125	$ 865,852,969
Range Totals	**$ 2,968,638,750**	**$ 3,339,718,594**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.5.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Goose Lake Reservoir could be used to supplement Columbia River instream flows for anadromous fish and could be released during April through August when 2000 BiOp target flows are not met at McNary Dam. The Goose Lake Reservoir would store enough water to meet a range of 36 to 111 percent of the 2000 BiOp target flows at McNary Dam during a one-month period from April through August based on monthly average flows at Grand Coulee, Priest Rapids and Bonneville dams.

Agricultural Irrigation

An arbitrary distance of 50 miles for conveyance of stored water was used to estimate potential agricultural use. Beyond this distance, conveyance costs would make agricultural use uneconomical. Of the counties surrounding the potential Goose Lake dam and reservoir site, only Grant County has significant irrigated agriculture (446,183 acres). The north half of Grant County lies within the 50-mile conveyance distance assumed for agricultural water use and could benefit from irrigation water conveyed from the Goose Lake site.

M&I Water Supply

There would be minimal potential benefits from using Goose Lake storage water for an M&I water supply. Nearby cities and towns include Omak, Okanogan, Coulee Dam and Nespelem, each with populations under 5,000, and local water supplies are expected to be sufficient to continue meeting future M&I water supply needs.

Recreation

There would be some opportunities for recreational boating on the potential Goose Lake reservoir. There is a limited warm-water fishery in Goose Lake; therefore, development of a fishing resource would require fish stocking and fisheries management in the potential reservoir.

5.2.5.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.5.8 Regional and Local Geology

The Goose Lake site is at the north edge of the Columbia Plateau, a structural and topographic basin that encompasses most of the Columbia River drainage. Most of the Columbia Plateau is underlain by Miocene basalts of the Columbia River Basalt Group, although bedrock exposed at this site and others along the north edge of the Columbia Plateau consist of Precambrian to lower Tertiary rocks of the Okanogan Highlands (Drost and Whiteman, 1986; Drost et al., 1990). At the Goose Lake site and vicinity, the exposed bedrock consists of pre-Tertiary metasedimentary rocks. The Miocene Wanapum Basalt is exposed in high outcrops northwest of the site (Drost and Whiteman, 1986, Schuster, 1992). The age of the metasedimentary rocks suggest that surfaces may be weathered. Quaternary alluvial sediments are present in the canyon floor, although the nature and thickness of these sediments were not determined for this characterization. A series of structural folds (synclines, anticlines, and at least one monocline) are present 10 to 15 miles west and southwest of the site. No other major structural features have been identified (Drost and Whiteman, 1986).

5.2.5.9 Potential Environmental and Institutional Issues

There would be no direct impacts on anadromous fish populations from construction and operation of a dam and reservoir at this site. Resident fish species and other aquatic life inhabit Goose Lake, which would be inundated by the potential reservoir. Goose Lake has a mean depth of 3 feet, a maximum depth of 7 feet, and covers approximately 248 acres (Colville Confederated Tribes, 1984). Goose Lake currently provides a limited recreational fishery for warm water fish species, including largemouth bass. The reservoir would inundate approximately 382 acres of NWI wetlands at full pool elevation. The potentially inundated area is not located within a designated wildlife preserve. However, Goose Lake is recognized to provide special hunting or wildlife habitat as documented in the surface water classifications for the Colville 208 Planning Program (Colville Confederated Tribes, 1984). Goose Lake provides special or unique ecological resources, including significant waterfowl breeding, nesting and brooding habitat in the wetlands associated with the lake. Peregrine falcons have been sighted hunting in the Goose Lake area. Other smaller lakes and springs and adjacent wetlands that would be inundated include Alkali Lake, Kartar Spring, Hidden Lake, Rat Lake, Buggy Spring, and Stinking Lake. Some of these lakes are saline.

The dam and reservoir site would be located entirely within the Colville Indian Reservation boundaries and the Colville Confederated Tribes would have to be consulted concerning potentially sensitive sites with respect to natural resources, cultural resources and other trust resources within the potential project boundary. The Goose Lake area is known to contain archaeological resources. The Colville Indian Reservation has an approved 208 Water Quality Management Plan (Colville Confederated Tribes, 1984), and water quality is regulated under the Colville Water Quality Standards Act, as amended.

A two-lane highway, existing roads, structures and several buildings would be inundated by the potential reservoir. An electric power transmission line runs through Goose Flats to a substation, both of which would be inundated by the potential reservoir. Portions of several farms, including some irrigated cropland and dry land farming areas, could be inundated by the potential reservoir. Portions of Goose Flats also provide livestock range, which would be inundated by the potential reservoir. Goose Lake is classified as suitable for supplying agricultural and livestock water, and the shorelines have been documented as being heavily impacted by livestock grazing (Colville Confederated Tribes, 1984).

The Washington State GAP Analysis database (WAGAP, 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with predicted habitat or recorded occurrences in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. Habitat in the Goose Lake Reservoir site is generally grassland and mesic steppe, except for Goose Lake itself and associated wetlands. In higher elevations to the east there is closed conifer forest with lodgepole and ponderosa pine and Douglas fir. Table 5-12 summarizes listed vertebrate species that have potential habitat in the area of the potential Goose Lake dam and reservoir site.

Table 5-12. Listed Vertebrate Species With GAP Habitat in the Goose Lake Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Columbia spotted frog	*Rana lutreiventris*	NL	SC
Sagebrush lizard	*Sceloporus graciosus*	NL	SC
Western toad	*Bufo borealis*	NL	SC
Black-backed woodpecker	*Picoides arcticus*	NL	SC
Golden eagle	*Aquila chryseatos*	NL	SC
Lewis' woodpecker	*Melanerpes lewis*	NL	SC
Loggerhead shrike	*Lanius ludovicianus*	NL	SC
Pileated woodpecker	*Dryocopus pileatus*	NL	SC
Sage sparrow	*Amphispiza belli*	NL	SC
Sage thrasher	*Oreoscoptes montanus*	NL	SC
Vaux's swift	*Chaetura vauxi*	NL	SC
Townsend's big-eared bat	*Coryhorhinus townsendii*	NL	SC
White-tailed jack rabbit	*Lepus townsendii*	NL	SC

Notes:
[1] NL = Not Listed
[2] SC = State Candidate

Small animals with limited dispersal capacity and home ranges impacted by dam construction or inundated by the reservoir would be at greatest risk. Large mobile species and birds could disperse from the construction and inundation zones. Bats would generally not be impacted unless a dam or reservoir would cover or inundate a hibernaculum. The listed species have potential habitat in the reservoir area, but no observations have been recorded.

One plant species is listed by the Washington Natural Heritage Program (WNHP, 2005) near the Goose Creek site – adder's tongue (*Ophioglossum pusillum*). The map scale does not allow definitive inclusion/exclusion at the site; if the site is considered for development, a specific survey for the species should be performed.

5.2.5.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Goose Lake site would involve the following environmental and institutional issues of concern:

- Approximately 382 acres of NWI wetlands would be impacted, requiring a Clean Water Act Section 404 permit and mitigation.
- The site is located within the boundaries of the Colville Indian Reservation and the Colville Confederated Tribes would have to be consulted concerning potentially sensitive sites with respect to natural resources, cultural resources and other trust resources within the potential project boundary.
- Potential impacts on Indian Trust Assets must be considered, evaluated, analyzed and mitigated.

5.2.6 Foster Creek Dam and Reservoir Site

5.2.6.1 Site Location

The Foster Creek site is located south of Chief Joseph Dam on the Columbia River. The dam and reservoir would be located in north Douglas County in Township 29 North, Ranges 25 and 26 East on the USGS 1:100,000 scale Banks Lake, Washington topographic quadrangle (see Site 6 on Map 1). Map 8 shows the potential Foster Creek Dam and Reservoir location in Douglas County.

5.2.6.2 Previous Investigations

Corps of Engineers

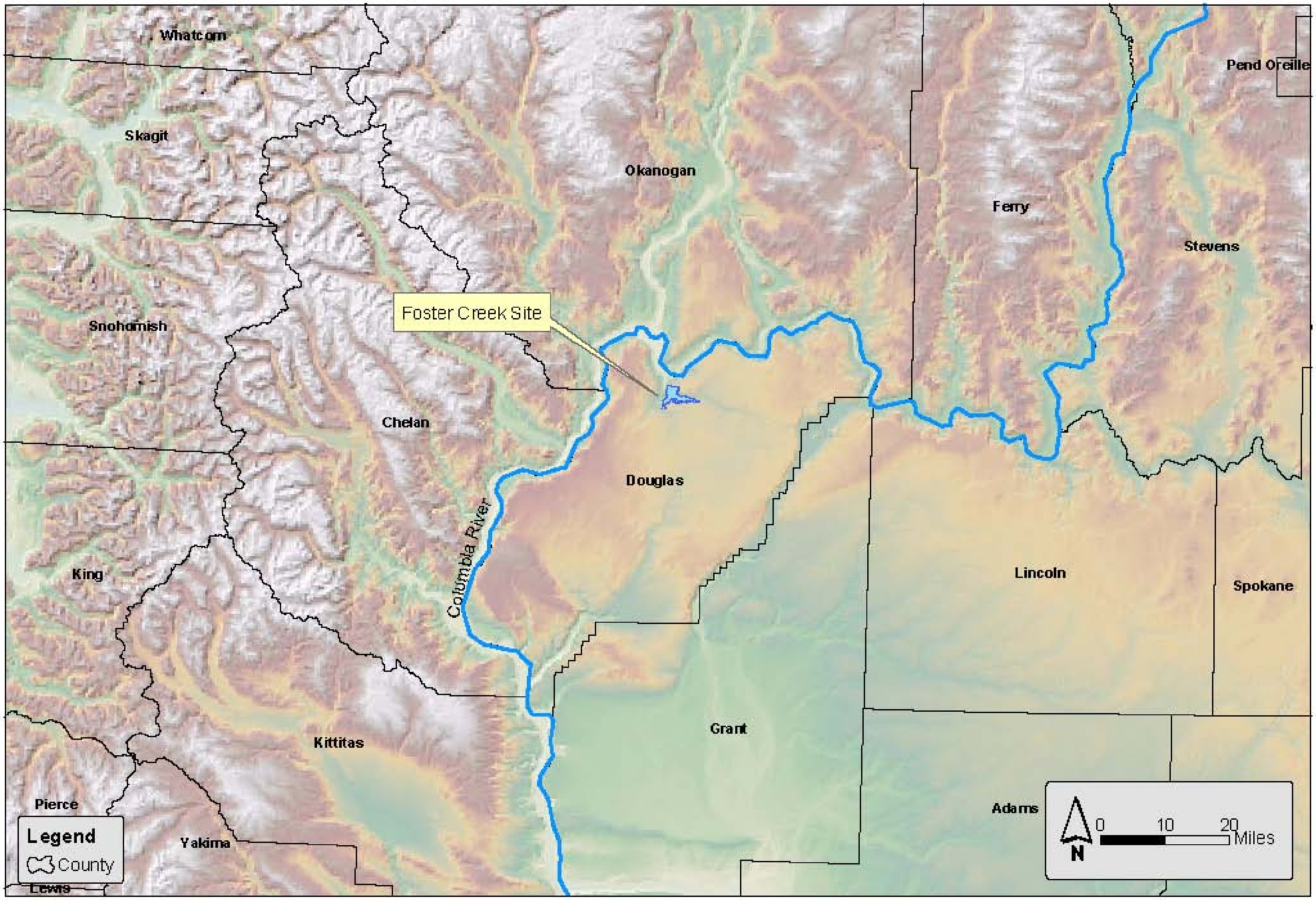
1976 Report. A Foster Creek site (called “Banks Lake – East Foster Creek”) is discussed briefly in the Corps of Engineers report entitled “Pumped-Storage in the Pacific Northwest, an Inventory” (North Pacific Division, Portland OR, Report No. 26, January 1976). Details of the dam and reservoir size and configuration or power generation potential are not given in that report, it is currently classified as “inactive.” From the description given, it appears that the site in the 1976 report is located much farther east than the currently proposed site, near the headwaters of East Foster Creek and the “Foster Coulee” that drains into Banks Lake.

5.2.6.3 Current Analysis

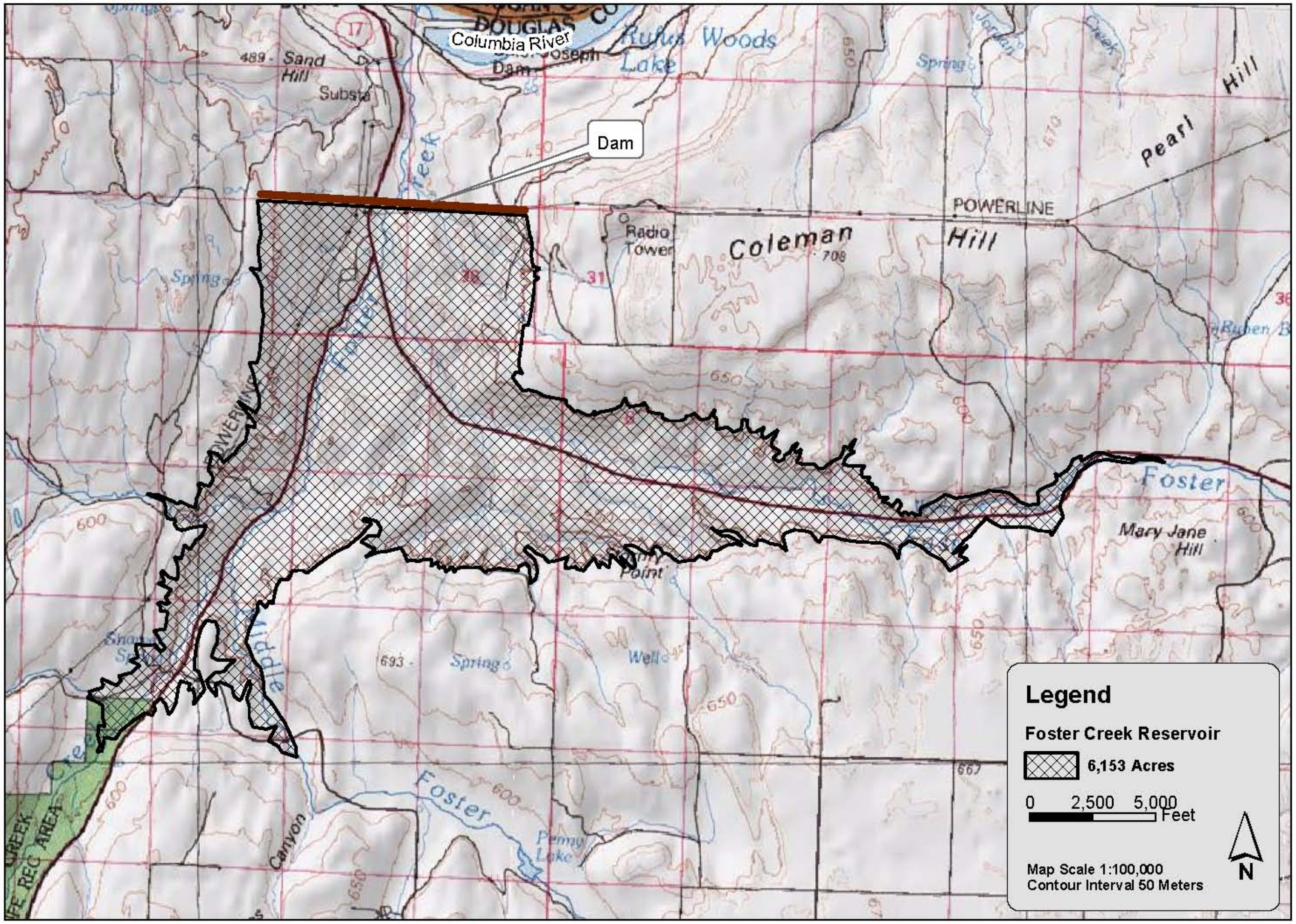
The Foster Creek dam and reservoir site would have a full-pool elevation at 1,600 feet MSL and would inundate portions of the Middle and East Forks of Foster Creek (see Map 9). Figure 5-13 shows the elevation-capacity-area curve for the potential Foster Creek reservoir. Figure 5-14 shows a cross-section of the proposed dam site looking downstream.

Reservoir Volume

Total potential storage volume is estimated at approximately 1,340,000 acre-feet. Usable storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 1,210,000 acre-feet.



Map 8
Foster Creek Dam and Reservoir Location Map



Map 9
Foster Creek Dam and Reservoir Site Map

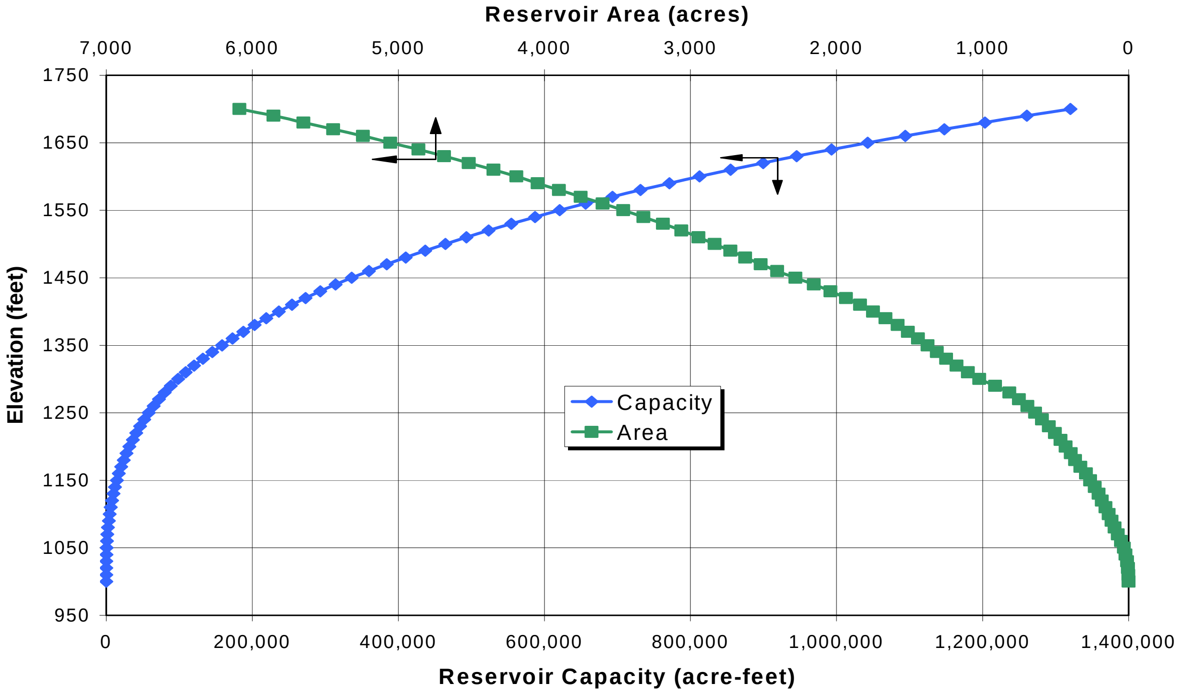


Figure 5-13. Foster Creek Reservoir Elevation-Capacity-Area Curves

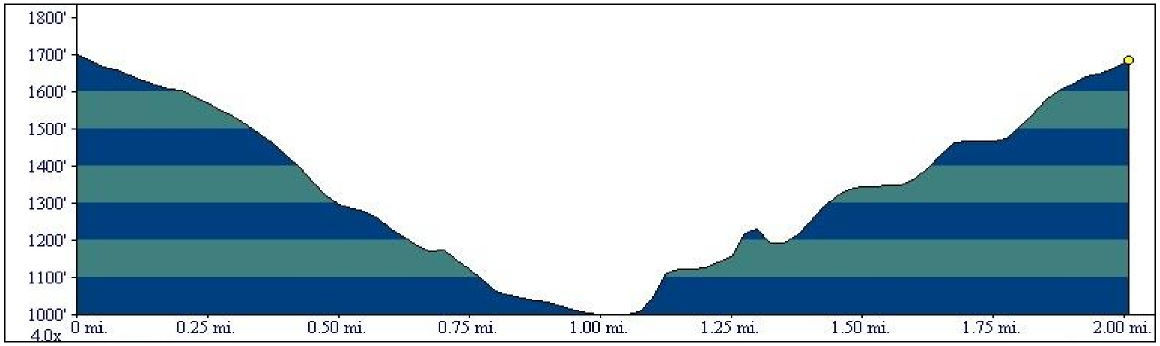


Figure 5-14. Foster Creek Dam Cross Section

Inundated Area

The inundated surface area at full-pool elevation would be approximately 6,150 acres.

Dam Size

The main dam would be approximately 11,000 feet long by 700 feet high, including a 10-foot freeboard.

5.2.6.4 Water Sources and Availability

No flow data is available for Foster Creek. In comparison to the flow pumped from the Columbia River, natural inflows at the dam site would be negligible. The diversion point would be in Rufus Woods Lake, which is impounded by Chief Joseph Dam. Water availability would be the same as was previously presented in section 5.2.5.4 for the Goose Lake Dam and Reservoir site.

5.2.6.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Foster Creek Dam and Reservoir is shown in Table 5-13.

Table 5-13. Pre-Appraisal-Level Cost Estimate for Foster Creek Dam and Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	$ 1,258,000,000	
2. Spillway/Outlet Works	$ 120,000,000	
3. Pumping Plant, Pumps & Motors	$ 209,000,000	
4. Waterway (tunnel)	$ 56,000,000	
Sub-Total (Field Costs)	$ 1,643,000,000	
Allowances		
Mobilization (5% x Field Costs)	$ 82,150,000	
Sub-Total (Field Costs plus Mobilizaton)	$ 1,725,150,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	$ 258,772,500	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	$ 1,983,922,500	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	$ 495,980,625	
Direct Construction Costs	$ 2,479,903,125	
Indirect Costs (20% to 35% of Direct Construction Costs)	$ 495,980,625	$ 867,966,094
Range Totals	**$ 2,975,883,750**	**$ 3,347,869,219**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.6.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Foster Creek Reservoir could be used to supplement Columbia River instream flows for anadromous fish and could be released during April through August when 2000 BiOp target flows are not met at McNary Dam. The Foster Creek Reservoir would store enough water to meet a range of 13 to 40 percent of the 2000 BiOp target flows at McNary Dam during a one-month period from April through August based on monthly average flows at Grand Coulee, Priest Rapids and Bonneville dams.

Agricultural Irrigation

An arbitrary distance of 50 miles for conveyance of stored water was used to estimate potential agricultural use. Beyond this distance, conveyance costs would make agricultural use uneconomical. Most of Douglas (21,199 irrigated acres - IA), the northern half of Grant (446,183 IA) and western Lincoln (47,984 IA) Counties lie within the 50-mile range for irrigation water. The Foster Creek site could be a positive resource for agricultural irrigation in a three-county area.

M&I Water Supply

There would be minimal potential benefits from using Foster Creek storage water for an M&I water supply. Cities and towns within a 50-mile radius include Bridgeport (pop. 2,100), Wenatchee (pop. 28,000), Ephrata (pop. 6,800) and Chelan (pop. 3,500). Local water supplies are expected to be sufficient to continue meeting future M&I water supply needs.

Recreation

There would be some opportunities for recreational boating on the potential Foster Creek reservoir. Development of a fishing resource would require fish stocking and fisheries management in the potential reservoir.

5.2.6.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.6.8 Regional and Local Geology

The Foster Creek site is located in a wide canyon on Foster Creek near the north-central edge of the Columbia Plateau, a structural and topographic basin that encompasses most of the Columbia River drainage. Exposed rock in the canyon walls at this site is the Grande Ronde Basalt, a lower Miocene unit of the Columbia River Basalt Group consisting of multiple flows with rare sedimentary interbeds. The Grande Ronde Basalt is probably only a few hundred feet thick at this location and may be weathered at the top of the highest flow. Overlying the Grande Ronde Basalt in the downcut canyon walls is the middle to upper Miocene Wanapum Basalt, which is probably only a few hundred feet thick in this vicinity but is widely exposed at the surface to the south, east, and west (Drost and Whiteman, 1986). Exposed rock outcrops are not extensively weathered. Contacts between individual flows in both the Grande Ronde and Wanapum basalts are sometimes rubbly and fractured, and these contact zones tend to be zones of higher permeability. The contact between the Grande Ronde and Wanapum basalts often is divided in places by the Vantage Member of the Ellensburg Formation, typically expressed as a siltstone or tuffaceous conglomerate, which may be 25 feet or more in thickness (Drost and Whiteman, 1986; Swanson et al., 1979). Alluvial sediments of unknown thickness cover the valley floor. Sediments described in the vicinity consist primarily of silt and fine sand, with some gravelly sand and cobble, and well-graded mixtures (NRCS, 2005). A series of structural folds (synclines, anticlines, and monoclines) are present in the vicinity. No other major structural features have been identified at this location (Drost and Whiteman, 1986).

5.2.6.9 Potential Environmental and Institutional Issues

There would be no direct long-term impacts on anadromous fish populations from construction and operation of a dam and reservoir at this site. The proposed dam site is approximately 0.25 miles upstream from a 35-foot high concrete dam that was constructed in the early 1900s (WRIA 44/50, Final Phase 2 Basin Assessment, 2003). The old dam was placed at the site of a natural falls that was a barrier to anadromous fish passage. Steelhead and salmon have year-round access to and utilize the 1-mile reach of Foster Creek below the old dam; construction of the proposed dam could cause temporary effects on water quality in that reach.

The Chief Joseph Dam power substation would be approximately ½-mile below the proposed dam location and major transmission lines cross Foster Creek below the proposed dam site. Other large transmission lines follow the Middle Fork Foster Creek south and would cross the inundated area; these may need to be relocated.

State Highway 17 and Bridgeport Hill Road would be inundated by the reservoir. There is some agricultural development within the full-pool reservoir boundary, but no major structures would be inundated. The reservoir area is not within a designated wildlife reserve. The NWI has no recorded wetlands in the potential reservoir area.

The Washington State GAP Analysis database (WAGAP, 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with predicted habitat or recorded occurrences in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. Habitat in the Foster Creek reservoir site is comprised mainly of non-forested; disturbed steppe, usually dominated by Bromus tectorum and other exotics flanked by areas of agriculture (winter wheat). Table 5-14 summarizes listed vertebrate species that have potential habitat in the area of the potential Foster Creek dam and reservoir site.

Table 5-14. Listed Vertebrate Species w/GAP Habitat in Foster Creek Dam and Reservoir Site			
Common Name	**Scientific Name**	**Federal Status[1]**	**State Status[2]**
Columbia spotted frog	*Rana lutreiventris*	NL	SC
Sagebrush lizard	*Sceloporus graciosus*	NL	SC
Black-backed woodpecker	*Picoides arcticus*	NL	SC
Golden eagle	*Aquila chryseatos*	NL	SC
Loggerhead shrike	*Lanius ludovicianus*	NL	SC
Sage grouse	*Centrocerus urophasianus*	NL	ST
Sage sparrow	*Amphispiza belli*	NL	SC
Sage thrasher	*Oreoscoptes montanus*	NL	SC
Sharp-tailed grouse	*Tympanuchus phasianellus*	NL	ST
Black-tailed jack rabbit	*Lepus californicus*	NL	SC
Merriam's shrew	*Sorex merriami*	NL	SC
Townsend's big-eared bat	*Coryhorhinus townsendii*	NL	SC
White-tailed jack rabbit	*Lepus townsendii*	NL	SC
Notes: 1: NL = Not Listed 2: SC = State Candidate; ST = State Threatened			

Small animals with limited dispersal capacity and home ranges impacted by dam construction or inundated by the reservoir would be at greatest risk. Large mobile species and birds could disperse from the construction and inundation zones. Bats would generally not be impacted unless a dam or reservoir would cover or inundate a hibernaculum. The herp species have potential habitat in the area of the reservoir, but no observations. Sharp-tailed grouse may have bred near the reservoir; the other bird species have potential habitat present without observations. The listed mammal species have potential habitat in the reservoir area, but no observations have been recorded.

5.2.6.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Foster Creek site would involve the following environmental and institutional issues of concern:

- State Highway 17 would be inundated by the reservoir.
- Local roads would be inundated by the reservoir.
- Power transmission line facilities would be inundated by the reservoir.
- Some agricultural land (winter wheat) would be inundated by the reservoir.
- Sharp-tailed grouse, a State of Washington threatened species, has been observed in the area and suitable habitat would inundated by the reservoir.

5.2.7 Twisp River Dam and Reservoir Site

The Twisp River Dam and Reservoir site is located north of the Columbia River in Okanagan County west of the town of Twisp on the Methow River (see Site 7 on Map 1). The site exceeds the 10-mile distance from the Columbia River and 800-foot pumping lift assumptions and was not evaluated in detail.

5.2.8 Eagle Creek Dam and Reservoir Site

The Eagle Creek Dam and Reservoir site is located in Chelan County west of the Columbia River and north of the town of Leavenworth (see Site 8 on Map 1). The site exceeds the 10-mile distance from the Columbia River and 800-foot pumping lift assumptions and was not evaluated in detail.

5.2.9 Mission Creek Dam and Reservoir Site

5.2.9.1 Site Location

The Mission Creek site is located south of the town of Cashmere on the Wenatchee River. The dam and reservoir would be located in south Chelan County approximately 7.7 miles from the Columbia River. The site is located in Townships 22 and 23 North, Ranges 18 and 19 East on the USGS 1:100,000 scale Wenatchee, Washington topographic quadrangle (see Site 9 on Map 1). Map 10 shows the potential Mission Creek Dam and Reservoir location in Chelan County.

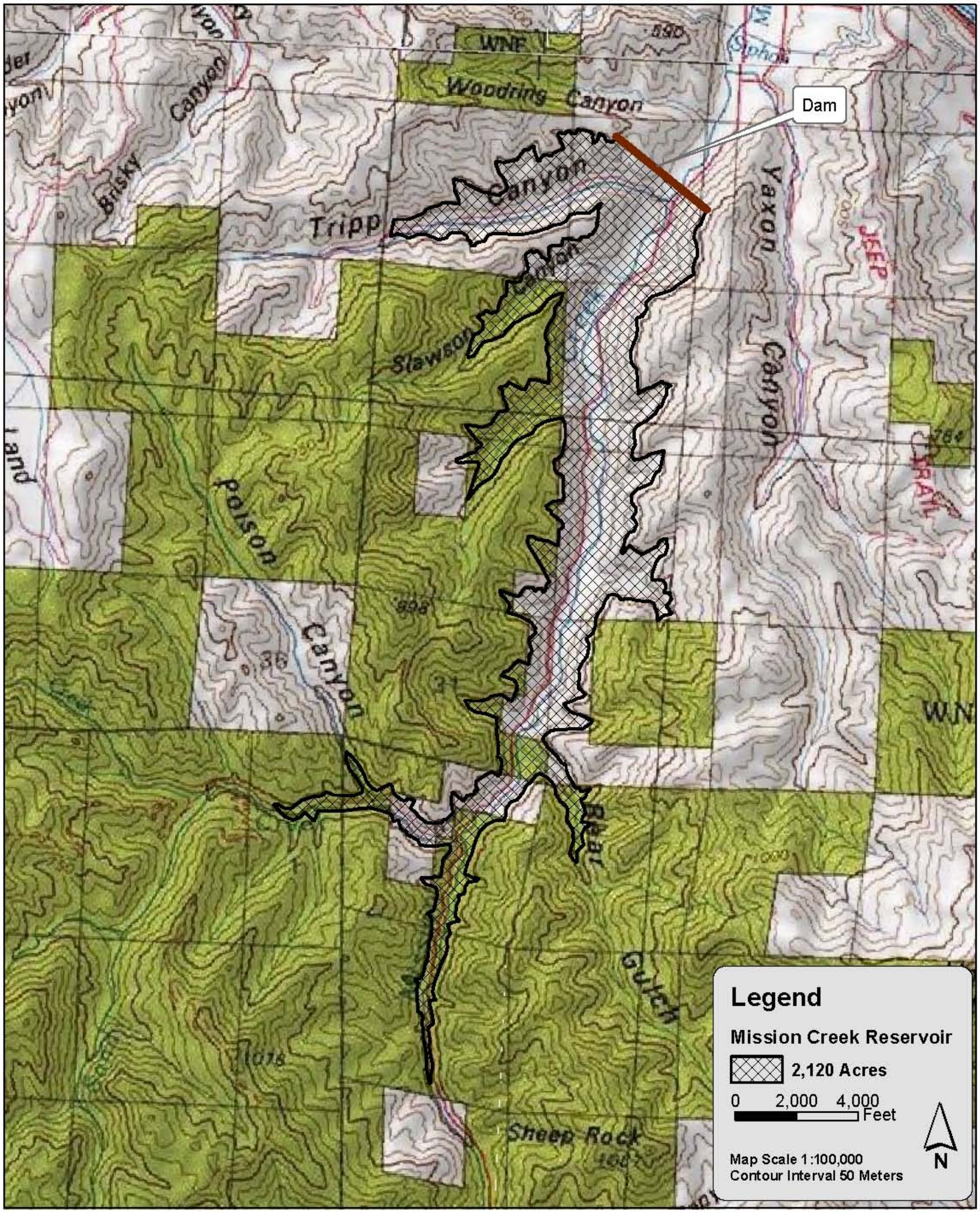
5.2.9.2 Previous Investigations

None identified.

5.2.9.3 Current Analysis

The Mission Creek dam and reservoir site would have a full-pool elevation at 1,600 feet MSL and would inundate portions of Mission Creek, Tripp, Sherman and Slawson canyons and Bear Gulch (see Map 11). Figure 5-15 shows the elevation-capacity-area curve for the potential Mission Creek reservoir.
Figure 5-16 shows a cross-section of the proposed dam site looking downstream.

Map 10
Mission Creek Dam and Reservoir Location Map



Map 11
Mission Creek Dam and Reservoir Site Map

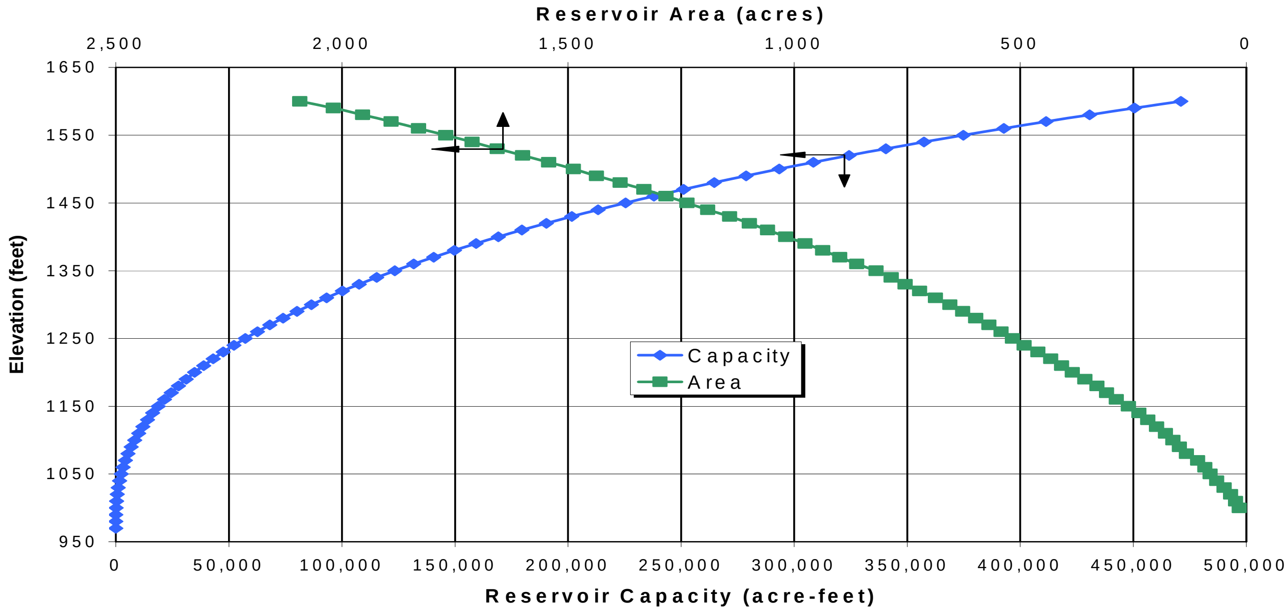


Figure 5-15. Mission Creek Reservoir Elevation-Capacity-Area Curves

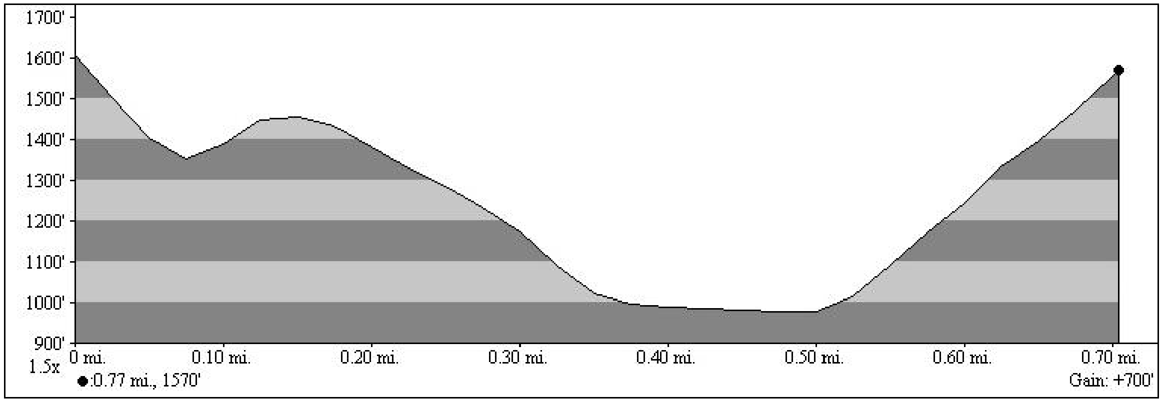


Figure 5-16. Mission Creek Dam Cross Section

Reservoir Volume

Total potential storage volume is estimated at approximately 470,000 acre-feet. Usable storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 420,000 acre-feet.

Inundated Area

The inundated surface area at full-pool elevation would be approximately 2,100 acres.

Dam Size

The dam would be approximately 3,800 feet long by 630 feet high, including a 10-foot freeboard (see Figure 5-16 for the dam site cross section).

5.2.9.4 Water Sources and Availability

The Mission Creek Reservoir would have a drainage area of about 80 square miles. The average annual inflow at the dam site would be on the order of about 20,000 ac-ft per year. This inflow is minor in comparison to the potential reservoir capacity, and it is insignificant in comparison to the more than 20,000,000 acre-feet of water that would be available for pumping from the Columbia River.

The diversion point would be in Lake Entiat, which is impounded by Rocky Reach Dam. The HYDROSIM model does not determine total Columbia River flow at Rocky Reach Dam. The drainage area at Rock Island Dam (87,800 square miles) is between the drainage area at Chief Joseph Dam (75,000 square miles) and the drainage area at Priest Rapids Dam (95,000 square miles). The water availability at Chief Joseph Dam and Priest Rapids Dam is presented in section 5.2.5.4. The water availability at Rocky Reach Dam was interpolated from the water availability at Chief Joseph Dam and Priest Rapids Dam based on difference in drainage areas at the dams. The water availability from the Columbia River to Mission Creek Reservoir is presented in Table 5-15.

Table 5-15. Total Water Availability at Lake Entiat (Rocky Reach Dam) (1000's of acre-feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	1,338	0	0	1,263	0	0	0	0	0	0	0	0	0	626	3,228
1930	1,792	0	0	0	363	0	0	0	0	0	0	0	0	813	2,968
1931	1,557	0	0	0	0	0	0	0	0	0	0	0	0	1,077	2,633
1932	1,641	0	0	0	0	2,175	596	955	2,471	224	210	0	0	784	9,055
1933	1,424	0	1,497	5,149	3,244	0	0	0	0	5,271	4,872	0	0	1,386	22,842
1934	2,774	2,494	9,546	13,220	7,435	4,679	2,708	857	713	0	0	0	0	715	45,141
1935	1,505	0	938	4,525	4,711	0	0	0	0	0	25	0	0	858	12,562
1936	1,627	0	0	0	0	120	0	0	3,776	0	0	0	0	432	5,956
1937	1,628	0	0	0	0	0	0	0	0	0	0	0	0	520	2,147
1938	1,788	0	807	5,904	901	3,477	58	0	3,520	0	0	0	0	851	17,305
1939	1,453	0	0	1,871	0	340	0	0	0	0	0	0	0	500	4,164
1940	1,777	0	316	991	174	3,379	0	0	0	0	0	0	0	376	7,014
1941	1,436	0	995	2,065	0	0	0	0	0	0	0	0	0	626	5,122
1942	1,262	0	3,623	5,577	251	0	0	0	0	166	459	0	0	572	11,909
1943	1,580	0	1,341	4,885	3,607	3,961	1,750	564	3,376	1,353	1,922	0	0	492	24,830
1944	1,410	0	86	1,702	0	0	0	0	0	0	0	0	0	716	3,914
1945	1,427	0	0	0	0	0	0	0	0	0	0	0	0	305	1,732
1946	1,639	0	225	3,056	2,105	4,147	472	38	4,256	0	818	0	0	874	17,630
1947	1,018	0	5,059	5,590	4,107	4,263	0	0	2,226	0	229	0	0	716	23,208
1948	3,919	1,643	2,820	5,986	1,180	1,982	79	0	4,172	14,704	2,522	0	0	1,828	40,834
1949	1,730	0	929	2,251	1,492	6,360	0	667	3,526	0	0	0	0	196	17,152
1950	1,442	0	149	3,037	4,934	7,375	736	272	1,697	7,349	3,496	0	0	1,111	31,599
1951	2,214	2,525	6,228	8,886	8,698	4,967	955	1,005	6,068	0	1,552	0	0	1,363	44,460
1952	3,039	397	3,259	4,906	3,147	2,894	396	211	5,123	0	0	0	0	508	23,879
1953	1,402	0	0	2,897	4,698	179	0	0	535	3,767	1,865	0	0	868	16,209
1954	1,698	79	2,317	4,049	4,735	2,494	668	0	3,047	6,009	3,699	923	0	4,323	34,042
1955	2,378	1,129	1,996	1,019	0	0	0	0	0	6,857	5,908	0	0	1,000	20,287
1956	2,203	1,890	6,321	9,960	3,219	6,545	1,368	2,129	7,570	6,811	2,559	0	0	847	51,421
1957	1,669	0	2,616	3,479	0	2,476	1,229	0	3,639	5,411	0	0	0	504	21,023
1958	1,344	0	389	3,093	3,883	2,803	0	0	2,929	1,850	0	0	0	645	16,937
1959	1,351	988	3,633	8,625	4,911	2,509	1,129	0	1,330	4,689	3,121	0	0	3,886	36,172
1960	4,503	2,948	4,626	4,409	1,311	2,041	2,609	191	0	445	353	0	0	824	24,261
1961	1,587	543	948	3,932	4,875	3,876	1,320	0	374	7,878	0	0	0	381	25,714
1962	1,385	0	59	3,715	0	0	1,472	608	0	0	0	0	0	515	7,753
1963	1,548	1,024	3,625	3,839	2,452	1,178	0	0	0	0	40	0	0	997	14,703
1964	1,213	0	366	3,606	649	0	0	0	0	5,612	4,538	0	0	1,637	17,621
1965	2,670	157	7,256	10,723	8,028	5,028	316	602	3,674	1,763	232	0	0	652	41,101
1966	1,559	218	1,956	4,749	0	89	660	0	0	0	677	0	0	584	10,492
1967	1,333	0	1,158	5,696	5,936	632	831	0	0	6,656	3,540	0	0	1,198	26,980
1968	1,559	212	1,980	4,814	4,053	2,378	0	0	0	836	2,604	0	0	2,265	20,702
1969	2,431	1,504	2,840	7,956	4,735	3,109	2,376	1,055	6,127	588	180	0	0	621	33,522
1970	1,402	0	516	5,311	3,578	480	0	0	0	1,854	0	0	0	0	13,140
1971	1,162	0	440	7,524	9,153	3,934	554	447	6,735	4,558	3,121	0	0	792	38,420
1972	1,139	100	1,991	6,693	7,981	13,401	3,124	0	6,078	9,581	4,637	512	0	1,400	56,638
1973	1,511	0	2,511	5,459	0	0	0	0	0	0	0	0	0	0	9,481
1974	1,253	0	4,687	13,730	9,217	6,558	1,887	1,445	5,966	7,426	7,239	125	0	1,507	61,040
1975	1,126	0	780	4,971	2,431	3,883	0	0	2,127	2,529	4,902	0	0	782	23,532
1976	1,813	2,075	8,124	8,619	4,997	3,214	1,582	320	4,626	97	3,680	1,388	0	4,956	45,491
1977	1,698	0	304	1,911	0	0	0	0	0	0	0	0	0	421	4,334
1978	934	0	2,152	3,714	1,297	4,645	452	0	1,516	0	1,090	0	0	1,015	16,816
Average	1,726	399	2,028	4,507	2,770	2,431	587	227	1,944	2,286	1,402	59	0	1,017	21,382
Maximum	4,503	2,948	9,546	13,730	9,217	13,401	3,124	2,129	7,570	14,704	7,239	1,388	0	4,956	61,040
Minimum	934	0	0	0	0	0	0	0	0	0	0	0	0	0	1,732
# Years of Avail. Water	50	17	41	44	35	35	25	16	27	26	29	4	0	48	50

5.2.9.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Mission Creek Dam and Reservoir is shown in Table 5-16.

Table 5-16. Pre-Appraisal-Level Cost Estimate for Mission Creek Dam and Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	$ 417,000,000	
2. Spillway/Outlet Works	$ 40,000,000	
3. Pumping Plant, Pumps & Motors	$ 136,000,000	
4. Waterway (tunnel)	$ 89,000,000	
Sub-Total (Field Costs)	$ 682,000,000	
Allowances		
Mobilization (5% x Field Costs)	$ 34,100,000	
Sub-Total (Field Costs plus Mobilizaton)	$ 716,100,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	$ 107,415,000	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	$ 823,515,000	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	$ 205,878,750	
Direct Construction Costs	$ 1,029,393,750	
Indirect Costs (20% to 35% of Direct Construction Costs)	$ 205,878,750	$ 360,287,813
Range Totals	**$ 1,235,272,500**	**$ 1,389,681,563**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.9.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Mission Creek Reservoir could be used to supplement Columbia River instream flows for anadromous fish and could be released during April through August when 2000 BiOp target flows are not met at McNary Dam. The Mission Creek Reservoir would store enough water to meet a range of 4 to 14 percent of the 2000 BiOp target flows at McNary Dam during a one-month period from April through August based on monthly average flows at Grand Coulee, Priest Rapids and Bonneville dams.

Agricultural Irrigation

An arbitrary distance of 50 miles for conveyance of stored water was used to estimate potential agricultural use. Beyond this distance, conveyance costs would make agricultural use uneconomical. Part of Douglas (21,199 irrigated acres - IA), Grant (446,183 IA) and Kittitas (75,859 IA) Counties lie within the 50-mile range for irrigation water. The Mission Creek site could be a resource for agricultural irrigation in a three-county area.

M&I Water Supply

There would be minimal potential benefits from using Mission Creek storage water for an M&I water supply. The only population center of note within a 50-mile radius of the site would be Wenatchee (pop. 28,000), but local water supplies are expected to be sufficient to continue meeting future M&I water supply needs.

Recreation

There would be some opportunities for recreational boating on the potential Mission Creek reservoir. Development of a fishing resource would require fish stocking and fisheries management in the potential reservoir. If a fish ladder was constructed at the dam, there could be a chinook and steelhead fishery in the reservoir and its tributaries.

5.2.9.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.9.8 Regional and Local Geology

The Mission Creek site is situated west of the Columbia River, near the northwest edge of the Columbia Plateau, a structural and topographic basin, which encompasses most of the Columbia River drainage. Most of the Columbia Plateau is underlain by Miocene basalts of the Columbia River Basalt Group, although bedrock exposed at this site and others along the west edge of the Columbia Plateau consist of Precambrian to lower Tertiary rocks of the Cascade Range (Drost and Whiteman, 1986). The proposed site is located overlying lower Tertiary sedimentary rocks with exposures of weathered bedrock in places (Schuster, 1992; Swanson et al;, 1979). Sediments may be 100 to 200 feet thick in places and consist of clay, silt, sands, gravels, and well-graded mixtures (Drost and Whiteman, 1986; NRCS, 1975). No major structural features are identified in this vicinity west of the Columbia River.

5.2.9.9 Potential Environmental and Institutional Issues

Mission Creek is located in the Wenatchee River Watershed, part of WRIA 45. Mission Creek is used by chinook salmon and steelhead trout. Without a fish ladder, the dam would be a barrier to fish passage approximately 2.4 miles above the mouth of Mission Creek.

There are no major utilities in the Mission Creek potential reservoir area. County Highway 11 and Tripp Canyon Road would be inundated, but there are no major traffic routes through the potential reservoir.

There are extensive orchards in the Mission Creek valley within the four miles upstream of the proposed dam site (up to the confluence with Bear Gulch) that would be inundated by the reservoir.

There are a number of residential and agricultural structures within the potential reservoir boundary that would need to be relocated. There are no wildlife refuges designated in the potential reservoir area. The reservoir would inundate approximately 4 acres of NWI wetlands at full pool elevation.

The Washington State GAP Analysis database (WAGAP, 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with predicted habitat or recorded occurrences in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. Habitat in the Mission Creek reservoir site contains extensive irrigated orchards in the valley floor, with grassland and mesic steppe occupying the slopes. At the southern extremity of the potential reservoir, the vegetation changes to a closed conifer forest, usually dominated by Douglas-fir, and including ponderosa pine, lodgepole pine and western larch. Table 5-17 summarizes listed vertebrate species that have potential habitat in the area of the potential Mission Creek dam and reservoir site.

Table 5-17. Listed Vertebrate Species With GAP Habitat in the Mission Creek Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Columbia spotted frog	*Rana lutreiventris*	NL	SC
Sagebrush lizard	*Sceloporus graciosus*	NL	SC
Western toad	*Bufo boreas*	NL	SC
Black-backed woodpecker	*Picoides arcticus*	NL	SC
Flammulated owl	*Otus flammeolus*	NL	SC
Golden eagle	*Aquila chryseatos*	NL	SC
Harlequin duck	*Histrionicus histrionicus*	NL	?
Lewis' woodpecker	*Melanerpes lewis*	NL	SC
Loggerhead shrike	*Lanius ludovicianus*	NL	SC
Pileated woodpecker	*Dryocopus pileatus*	NL	SC
Spotted owl	*Strix occidentalis*	T	SE
Vaux's swift	*Chaetura vauxi*	NL	SC
White-headed woodpecker	*Picoides alboarvatus*	NL	SC
Fisher	*Martes penanti*	NL	SC
Townsend's big-eared bat	*Coryhorhinus townsendii*	NL	SC
Western gray squirrel	*Sciurus griseus*	NL	SC

Notes:
[1] NL = Not Listed; T = Threatened
[2] SC = State Candidate; SE = State Endangered; ? = Listing status uncertain

Small animals with limited dispersal capacity and home ranges impacted by dam construction or inundated by the reservoir would be at greatest risk. Large mobile species and birds could disperse from the construction and inundation zones. Bats would generally not be impacted unless a dam or reservoir would cover or inundate a hibernaculum. The herp species have potential habitat in the area of the reservoir, but no observations. There are possible observations of breeding occurrences for loggerhead shrike; the other bird species have potential habitat present without observations. The listed mammal species have potential habitat in the reservoir area, but no observations have been recorded.

A number of listed plant species have been located near the Mission Creek site by the Washington Natural Heritage Program (WNHP 2005). The scale of the mapping does not allow a definitive inclusion/exclusion of these species and, if the site is considered for development, a specific inventory should be performed. The potential listed plant species are summarized in Table 5-18.

Table 5-18. Listed Plant Species in the Mission Creek Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Clustered lady's-slipper	*Cypripedium fasciculatum*	NL	T
Wenatchee larkspur	*Delphinium viridescens*	NL	T
Wenatchee mountain checker-mallow	*Sidalcea oregana var. calva*	E	E

Notes:
[1] NL = Not Listed; E = Endangered
[2] T = Threatened; E = Endangered

5.2.9.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Mission Creek site would involve the following environmental and institutional issues of concern:

- Mission Creek is habitat for federally-listed anadromous fish species, including chinook salmon and steelhead trout. The dam would be a barrier to anadromous fish passage and the reservoir would inundate anadromous and resident fish habitat in the creek.
- Approximately 4 acres of NWI wetlands would be impacted, requiring a Clean Water Act Section 404 permit and mitigation.
- County Highway 11 would be inundated by the reservoir.
- Local roads would be inundated by the reservoir.
- Extensive agricultural land (fruit orchards) would be inundated by the reservoir.
- Multiple residences and farm structures would be inundated by the reservoir.
- Northern spotted owl, a federally-listed threatened species, has suitable habitat within the reservoir area. This species also is listed as endangered by the State of Washington.
- Wenatchee mountain checker-mallow, a federally-listed endangered plant species, occurs in the Mission Creek area and could be inundated by the reservoir. This species also is listed as endangered by the State of Washington.

- Sharp-tailed grouse, a State of Washington threatened species, has been observed in the area and suitable habitat may inundated by the reservoir.
- Clustered lady's-slipper and Wenatchee larkspur, State of Washington threatened species, have been observed in the area and suitable habitat may be inundated by the reservoir.

5.2.10 Moses Coulee Dam and Reservoir Site

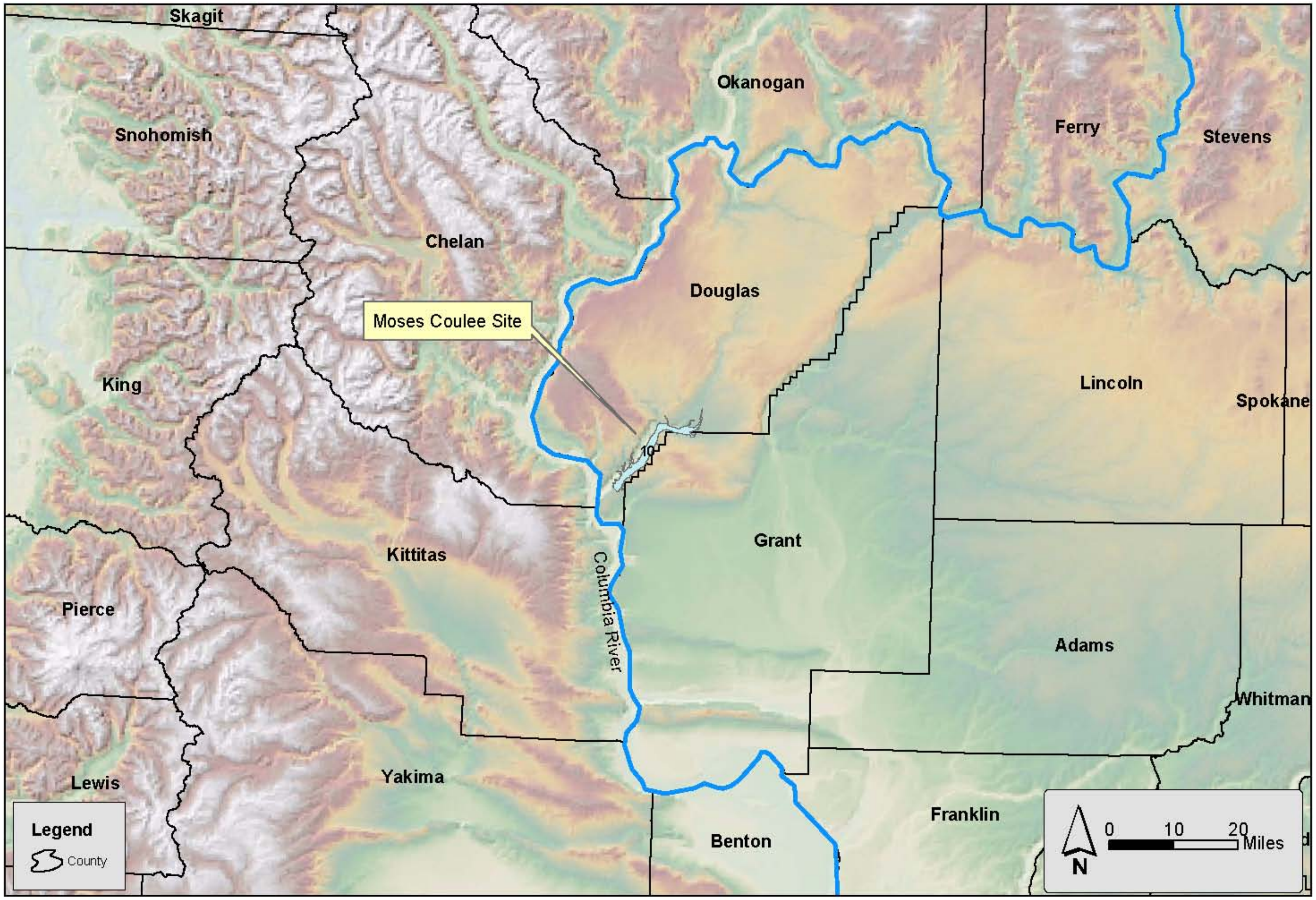
5.2.10.1 Site Location

The Moses Coulee site lies in a flood drainage channel from Pleistocene Lake Missoula, formed between 10,000 to 15,000 years ago. The dam and reservoir would be located in south Douglas County in Townships 21, 22 and 23 North, Ranges 23 and 24 East in the USGS 1:100,000 scale Moses Lake and Wenatchee, Washington topographic quadrangles (see Site 10 on Map 1). At full pool, the reservoir would be approximately 20 miles long. Irrigated farming occurs along the stream in the potential project area, with the remainder covered by natural semi-arid vegetation. Map 12 shows the potential Moses Coulee Dam and Reservoir location in Douglas County.

5.2.10.2 Previous Investigations

Corps of Engineers

1976 Report. Moses Coulee is discussed briefly in the Corps of Engineers report entitled "Pumped-Storage in the Pacific Northwest, an Inventory" (North Pacific Division, Portland OR, Report No. 26, January 1976). Details of the dam and reservoir size and configuration or power generation potential are not given in that report. The 1976 Corps report footnotes a report by Sol E Schultz and Harold M. Moser entitled "Pumped-Storage Cooling Water in Moses Coulee (American Water Resources Association, Proceedings Series No. 15, Pumped-Storage Development and its Environmental Effects, Urbana, IL, 1971, pp. 42-49). The primary purpose of that study was to provide cooling water for nuclear power plants; it is currently listed as "inactive."



Map 12
Moses Coulee Dam and Reservoir Location Map

5.2.10.3 Current Analysis

The Moses Coulee dam and reservoir site would have a full-pool elevation at 1,400 feet MSL (see Map 13). Figure 5-17 shows the elevation-capacity-area curve for the potential Moses Coulee reservoir. Figure 5-18 shows a cross-section of the proposed dam site looking downstream.

Reservoir Volume

Total potential storage volume is estimated at approximately 4,130,000 acre-feet. Usable storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 3,720,000 million acre-feet.

Inundated Area

The inundated surface area at full-pool elevation would be approximately 13,000 acres.

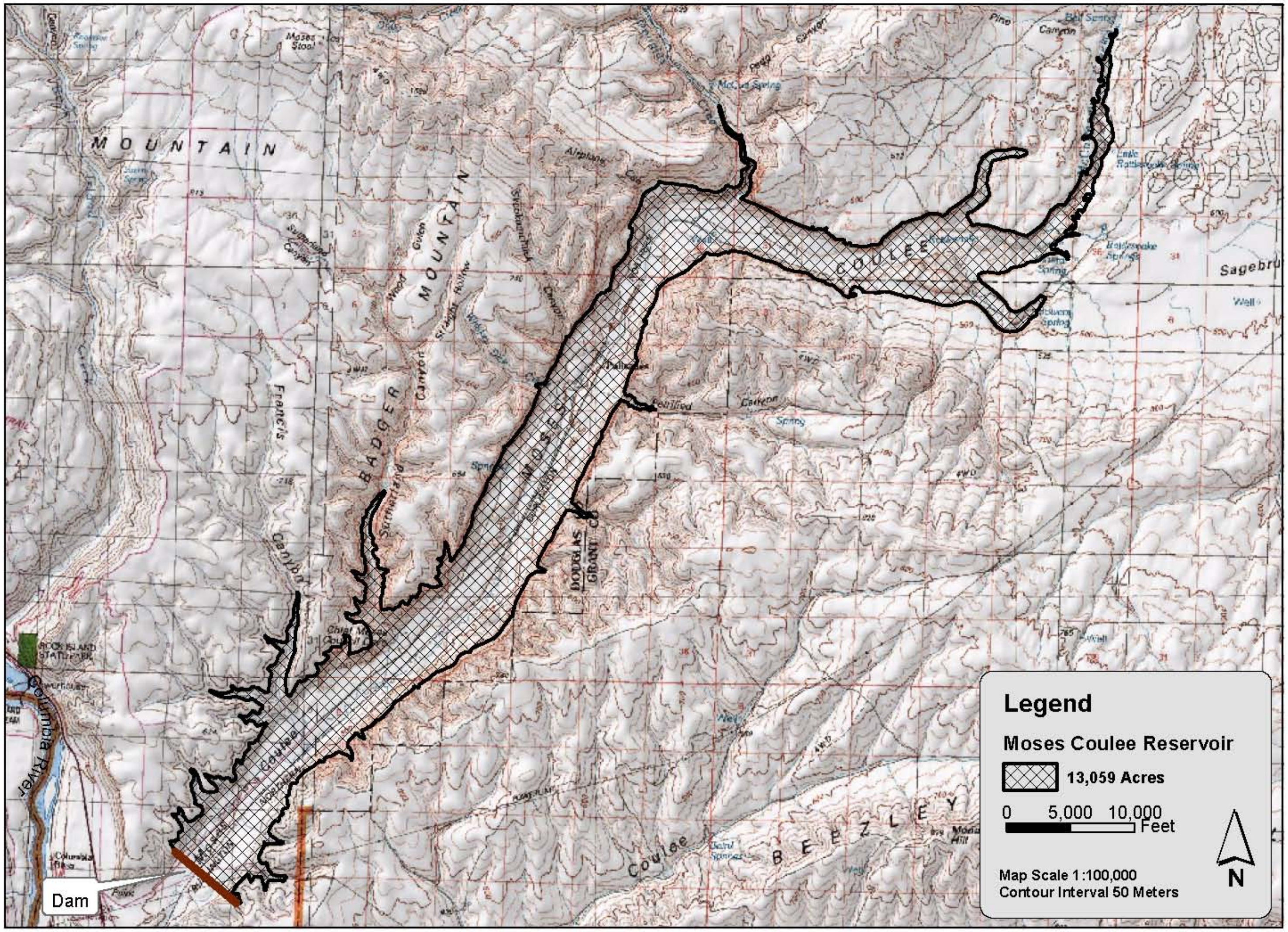
Dam Size

The main dam would be approximately 5,150 feet long by 605 feet high, including a 10-foot freeboard.

5.2.10.4 Water Sources and Availability

The Moses Coulee site receives water from Douglas Creek and McCarteney Creek and multiple springs upstream from the confluence of the Coulee with Douglas Creek. Jameson, Bennett and Grimes Lakes form the headwaters of the McCarteney Creek drainage that feeds into Moses Coulee. The lower portion of Moses Coulee was dredged and diked by the Corps of Engineers in 1927. Most of the lower Coulee supports only intermittent stream flow and there was no flow for years 2000 through 2003 (WRIA 44/50 Final Phase 2 Basin Assessment 2003). The natural inflows to the Moses Coulee site would be negligible in comparison to the inflow of water pumped from the Columbia River. The intake for the Moses Coulee site could be in the reservoir behind either Wanapum Dam or Rock Island Dam. To minimize the pumping head, the diversion point will be assumed to be in the reservoir behind Rock Island Dam.

The HYDROSIM model does not determine total Columbia River flow at Rock Island Dam. The drainage area at Rock Island Dam (89,400 square miles) is between the drainage area at Chief Joseph Dam (75,000 square miles) and the drainage area at Priest Rapids Dam (95,000 square miles). The water availability at Chief Joseph Dam and Priest Rapids Dam is presented in section 5.2.5.4. The water availability at Rock Island Dam was interpolated from the water availability at Chief Joseph Dam and Priest Rapids Dam based on difference in drainage areas at the dams. Water available for diversion to off-channel storage from the reservoir impounded by Rock Island Dam is presented in Table 5-19.



Map 13
Moses Coulee Dam and Reservoir Site Map

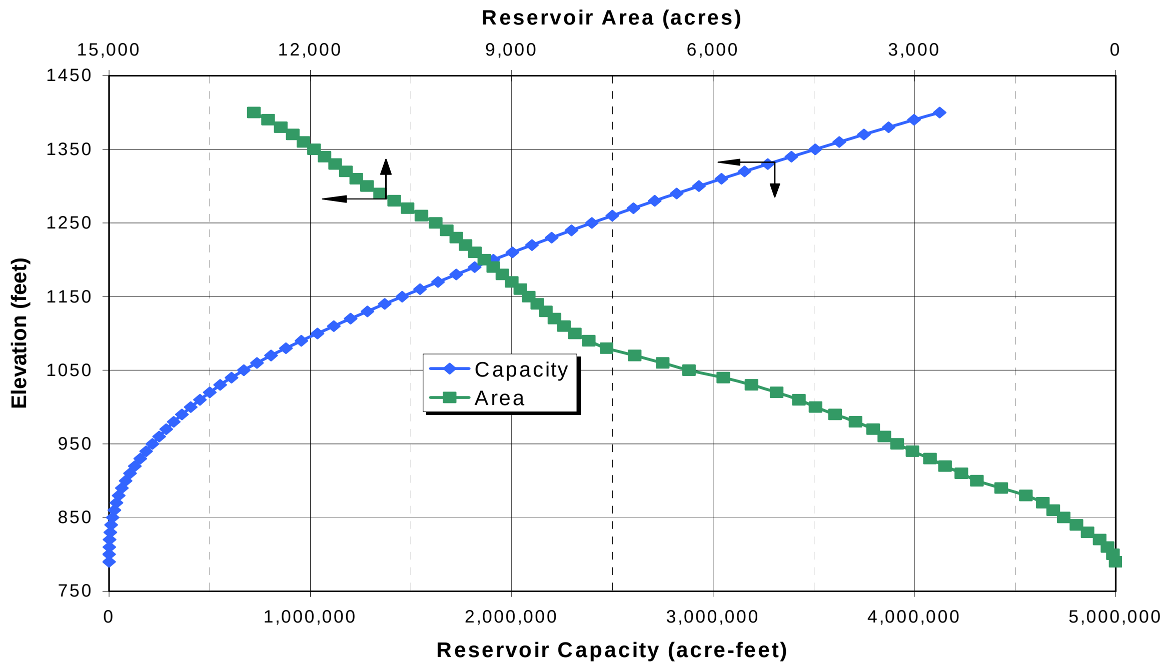


Figure 5-17. Moses Coulee Reservoir Elevation-Capacity-Area Curves

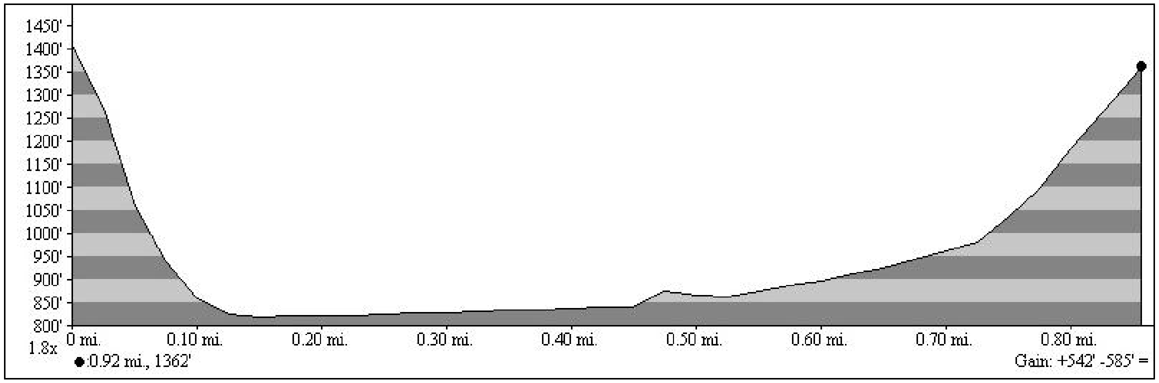


Figure 5-18. Moses Coulee Dam Cross Section

Table 5-19. Total Water Availability at Rock Island Dam and Reservoir (1000's of acre-feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	1,348	0	0	1,268	0	0	0	0	0	0	0	0	0	629	3,244
1930	1,803	0	0	0	365	0	0	0	0	0	0	0	0	817	2,984
1931	1,563	0	0	0	0	0	0	0	0	0	0	0	0	1,080	2,643
1932	1,646	0	0	0	0	2,194	598	958	2,486	226	211	0	0	787	9,107
1933	1,430	0	1,505	5,163	3,253	0	0	0	0	5,332	4,924	0	0	1,392	22,998
1934	2,790	2,513	9,586	13,258	7,463	4,712	2,727	871	722	0	0	0	0	718	45,360
1935	1,513	0	943	4,542	4,734	0	0	0	0	0	25	0	0	862	12,619
1936	1,635	0	0	0	0	121	0	0	3,797	0	0	0	0	433	5,986
1937	1,634	0	0	0	0	0	0	0	0	0	0	0	0	522	2,156
1938	1,796	0	811	5,918	905	3,491	58	0	3,544	0	0	0	0	852	17,375
1939	1,460	0	0	1,877	0	341	0	0	0	0	0	0	0	502	4,180
1940	1,784	0	318	995	175	3,391	0	0	0	0	0	0	0	377	7,039
1941	1,443	0	999	2,070	0	0	0	0	0	0	0	0	0	628	5,140
1942	1,272	0	3,639	5,596	253	0	0	0	0	167	460	0	0	574	11,960
1943	1,590	0	1,350	4,906	3,627	3,983	1,756	569	3,403	1,374	1,952	0	0	496	25,007
1944	1,419	0	87	1,707	0	0	0	0	0	0	0	0	0	720	3,933
1945	1,434	0	0	0	0	0	0	0	0	0	0	0	0	307	1,741
1946	1,649	0	226	3,071	2,113	4,165	474	38	4,295	0	825	0	0	880	17,737
1947	1,026	0	5,081	5,606	4,125	4,284	0	0	2,253	0	230	0	0	720	23,325
1948	3,933	1,654	2,833	6,003	1,188	1,990	80	0	4,199	14,882	2,555	0	0	1,847	41,165
1949	1,746	0	934	2,260	1,501	6,392	0	673	3,589	0	0	0	0	198	17,293
1950	1,451	0	150	3,048	4,952	7,406	741	274	1,715	7,448	3,545	0	0	1,121	31,851
1951	2,229	2,545	6,263	8,930	8,745	5,007	964	1,014	6,135	0	1,564	0	0	1,373	44,769
1952	3,056	400	3,275	4,923	3,163	2,910	397	213	5,153	0	0	0	0	509	23,999
1953	1,406	0	0	2,909	4,714	180	0	0	540	3,799	1,883	0	0	871	16,302
1954	1,707	79	2,327	4,060	4,751	2,504	671	0	3,072	6,062	3,743	929	0	4,348	34,253
1955	2,393	1,137	2,008	1,024	0	0	0	0	0	6,937	5,978	0	0	1,007	20,483
1956	2,217	1,907	6,346	9,985	3,232	6,571	1,376	2,146	7,667	6,933	2,588	0	0	852	51,819
1957	1,680	0	2,633	3,489	0	2,490	1,234	0	3,694	5,465	0	0	0	506	21,192
1958	1,349	0	391	3,102	3,897	2,817	0	0	2,968	1,870	0	0	0	647	17,042
1959	1,360	994	3,656	8,656	4,930	2,529	1,138	0	1,345	4,760	3,157	0	0	3,905	36,429
1960	4,540	2,974	4,663	4,422	1,320	2,051	2,625	193	0	452	357	0	0	827	24,424
1961	1,594	545	951	3,942	4,895	3,898	1,330	0	377	7,966	0	0	0	382	25,881
1962	1,388	0	59	3,719	0	0	1,474	612	0	0	0	0	0	515	7,766
1963	1,555	1,029	3,640	3,851	2,470	1,184	0	0	0	0	40	0	0	999	14,768
1964	1,218	0	368	3,613	651	0	0	0	0	5,683	4,578	0	0	1,641	17,753
1965	2,684	157	7,282	10,745	8,055	5,056	318	607	3,705	1,789	234	0	0	655	41,288
1966	1,563	219	1,963	4,752	0	90	665	0	0	0	681	0	0	585	10,518
1967	1,335	0	1,163	5,710	5,946	635	834	0	0	6,760	3,564	0	0	1,200	27,146
1968	1,566	214	1,992	4,835	4,085	2,392	0	0	0	848	2,623	0	0	2,270	20,825
1969	2,441	1,509	2,850	7,969	4,751	3,111	2,383	1,061	6,197	596	181	0	0	620	33,669
1970	1,412	0	519	5,327	3,592	484	0	0	0	1,880	0	0	0	0	13,212
1971	1,166	0	442	7,540	9,193	3,965	556	449	6,811	4,637	3,158	0	0	792	38,709
1972	1,143	101	1,997	6,706	8,007	13,495	3,144	0	6,165	9,783	4,703	515	0	1,404	57,164
1973	1,518	0	2,521	5,474	0	0	0	0	0	0	0	0	0	0	9,513
1974	1,263	0	4,712	13,754	9,247	6,582	1,896	1,451	6,022	7,559	7,323	126	0	1,508	61,444
1975	1,131	0	784	4,988	2,440	3,892	0	0	2,146	2,570	4,940	0	0	786	23,676
1976	1,828	2,092	8,195	8,662	5,005	3,245	1,593	323	4,686	99	3,712	1,400	0	4,985	45,824
1977	1,709	0	306	1,916	0	0	0	0	0	0	0	0	0	423	4,354
1978	935	0	2,170	3,720	1,301	4,665	456	0	1,530	0	1,098	0	0	1,019	16,893
Average	1,735	401	2,039	4,520	2,781	2,444	590	229	1,964	2,318	1,417	59	0	1,022	21,519
Maximum	4,540	2,974	9,586	13,754	9,247	13,495	3,144	2,146	7,667	14,882	7,323	1,400	0	4,985	61,444
Minimum	935	0	0	0	0	0	0	0	0	0	0	0	0	0	1,741
# Years of Avail. Water	50	17	41	44	35	35	25	16	27	26	29	4	0	48	50

5.2.10.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Moses Coulee Dam and Reservoir is shown in Table 5-20.

Table 5-20. Pre-Appraisal-Level Cost Estimate for Moses Coulee Dam and Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	$ 613,000,000	
2. Spillway/Outlet Works	$ 60,000,000	
3. Pumping Plant, Pumps & Motors	$ 262,000,000	
4. Waterway (tunnel)	$ 109,000,000	
Sub-Total (Field Costs)	$ 1,044,000,000	
Allowances		
Mobilization (5% x Field Costs)	$ 52,200,000	
Sub-Total (Field Costs plus Mobilizaton)	$ 1,096,200,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	$ 164,430,000	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	$ 1,260,630,000	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	$ 315,157,500	
Direct Construction Costs	$ 1,575,787,500	
Indirect Costs (20% to 35% of Direct Construction Costs)	$ 315,157,500	$ 551,525,625
Range Totals	**$ 1,890,945,000**	**$ 2,127,313,125**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.10.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Moses Coulee Reservoir could be used to supplement Columbia River instream flows for anadromous fish and could be released during April through August when 2000 BiOp target flows are not met at McNary Dam. The Moses Coulee Reservoir would store enough water to meet a range of 40 to 123 percent of the 2000 BiOp target flows at McNary Dam during a one-month period from April through August based on monthly average flows at Grand Coulee, Priest Rapids and Bonneville dams.

Agricultural Irrigation

An arbitrary distance of 50 miles for conveyance of stored water was used to estimate potential agricultural use. Beyond this distance, conveyance costs would make agricultural use uneconomical. Most of Douglas (21,199 irrigated acres - IA), Grant (446,183 IA) and Kittitas (75,859 IA) counties lie within the 50-mile range for irrigation water and minor portions of Adams (148,018 IA), Benton (153,254 IA) and Yakima (277, 389 IA) Counties are also within the range. The Moses Coulee site could be a significant resource for agricultural irrigation in a six-county area.

M&I Water Supply

There would be minimal potential benefits from using Moses Coulee storage water for an M&I water supply. Cities and towns within a 50-mile radius include Wenatchee (pop. 28,000), Ephrata (pop. 6,800), Moses Lake (pop. 15,000) and Ellensburg pop. 15,000). Local water supplies are expected to be sufficient to continue meeting future M&I water supply needs.

Recreation

There would be some opportunities for recreational boating on the potential Moses Coulee reservoir. Development of a fishing resource would require fish stocking and fisheries management in the potential reservoir.

5.2.10.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.10.8 Regional and Local Geology

The Moses Coulee site is east of the Columbia River, in the northwest part of the Columbia Plateau, a structural and topographic basin, which encompasses most of the Columbia River drainage. Exposed rock at this site is the Grande Ronde Basalt, a lower Miocene unit of the Columbia River Basalt Group consisting of multiple flows with rare sedimentary interbeds. The Grande Ronde Basalt is probably several hundred feet thick at this location and may be weathered at some flow tops. Contacts between individual flows in the Grande Ronde Basalts are sometimes rubbly and fractured, and these contact zones tend to be zones of higher permeability. On the valley floor, the basalt is overlain by 100 to 200 feet of Quaternary alluvial sediments (Drost and Whiteman, 1986; Swanson et al., 1979). A detailed description of soils was not found for this location. The Moses Coulee lies within the southward-dipping Moses Coulee Syncline and within a group of folds probably associated with Yakima Fold Belt. A high-angle normal fault is located across the valley upstream of the site (Drost and Whiteman, 1986).

5.2.10.9 Potential Environmental and Institutional Issues

There would be no direct impacts on anadromous fish populations from construction and operation of a dam and reservoir at this site. The reservoir would flood Douglas and McCarteney Creeks, but would not inundate Jameson Lake or other upstream lakes. Because the Coulee may be dry for years at a time, there is no fishery present. There are no wildlife preserves identified within the potential reservoir boundary.

A two-lane road (Palisades Road) and an abandoned Great Northern Railroad line would be inundated by the reservoir. No major transmission lines or waterways cross the reservoir inundation boundary. The townsite of Palisades lies in the upper part of the potential reservoir but appears to be abandoned.

A number of farms, including some irrigated cropland and orchards and dry land farming areas, would be inundated by the potential reservoir. Portions of Moses Coulee also could provide livestock range, which would be inundated by the potential reservoir. The reservoir would inundate approximately 4 acres of NWI wetlands at full pool elevation.

The Washington State GAP Analysis database (WAGAP, 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with habitat in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. Habitat in the Moses Coulee reservoir site is extensive arid grasslands and sagebrush interspersed with irrigated agriculture, bordered by basalt cliffs at the eastern end. Table 5-21 summarizes listed vertebrate species that have potential habitat in the area of the potential Moses Coulee dam and reservoir site.

Table 5-21. Listed Vertebrate Species With GAP Habitat in the Moses Coulee Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Sagebrush lizard	*Sceloporus graciosus*	NL	SC
Striped whipsnake	*Masticophis taeniatus*	NL	SC
Ferruginous Hawk	*Buteo regalis*	NL	ST
Golden eagle	*Aquila chryseatos*	NL	SC
Loggerhead shrike	*Lanius ludovicianus*	NL	SC
Sage grouse	*Centrocercus urophasianus*	C	ST
Sage sparrow	*Amphispiza belli*	NL	SC
Sage thrasher	*Oreoscoptes montanus*	NL	SC
Black-tailed jack rabbit	*Lepus californicus*	NL	SC
Merriam's shrew	*Sorex merriamii*	NL	SC
Pygmy rabbit	*Brachylagus idahoensis*	E	SE
Townsend's big-eared bat	*Coryhorhinus townsendii*	NL	SC
Washington ground squirrel	*Spermophilus washingtoni*	C	SC
White-tailed jack rabbit	*Lepus townsendii*	NL	SC

Notes:
[1] NL = Not Listed; C = Candidate; E = Endangered
[2] SC = State Candidate; ST = State Threatened; SE = State Endangered

Small animals with limited dispersal capacity and home ranges impacted by dam construction or inundated by the reservoir would be at greatest risk. Large mobile species and birds could disperse from the construction and inundation zones. Bats would generally not be impacted unless a dam or reservoir would cover or inundate a hibernaculum. The herp species have potential habitat in the area of the reservoir, but no observations. There are observations of breeding occurrences for loggerhead shrike and possible breeding of sage grouse, sage sparrow and sage thrasher near the Coulee; the other bird species have potential habitat present without observations. Black-tailed jack rabbits have potential habitat in the area of the reservoir. Potential habitat for white-tailed jack rabbit is marginal. Pygmy rabbit has been recorded in two townships overlying the Coulee.

A number of listed plant species have been located near the Moses Coulee site by the Washington Natural Heritage Program (WNHP, 2005). The scale of the mapping does not allow a definitive inclusion/exclusion of these species and, if the site is considered for development, a specific inventory should be performed. The potential listed plant species are summarized in Table 5-22.

Table 5-22. Listed Plant Species in the Moses Coulee Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Whited's milkvetch	*Astralagus sinuatus*	C	E
Dwarf evening-primrose	*Camissionia pygmaea*	NL	T
Chelan rockmat	*Petrophyton cinerascens*	C	T
Sticky phacelia	*Phacelia lenta*	C	T

Notes:
[1] NL = Not Listed; C = Candidate
[2] T = Threatened; E = Endangered

5.2.10.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Moses Coulee site would involve the following environmental and institutional issues of concern:

- Approximately 4 acres of NWI wetlands would be impacted, requiring a Clean Water Act Section 404 permit and mitigation.
- Palisades Road would be inundated by the reservoir.
- Other local roads would be inundated by the reservoir.
- An abandoned Great Northern Railroad line would be inundated by the reservoir
- The Palisades townsite, apparently abandoned and likely a historical resource, would be inundated by the reservoir.
- Agricultural land (irrigated cropland, fruit orchards and dry land farming areas) would be inundated by the reservoir.
- Multiple residences and farm structures would be inundated by the reservoir.
- Pygmy rabbit, a federally-listed endangered species, has been observed in the reservoir area and suitable habitat would be inundated by the reservoir. This species also is listed as endangered by the State of Washington.
- Greater sage grouse and Washington ground squirrel, federal candidate species, have suitable habitat within the reservoir area. The Greater sage grouse is listed as threatened by the State of Washington.

- Ferruginous hawk, a State of Washington threatened species, has been observed in the area and suitable habitat may inundated by the reservoir.
- Whited's milkvetch, Chelan rockmat and Sticky phacelia, are federal candidate plant species that occur in the Moses Coulee area and may be inundated by the reservoir. Whited's milkvetch is a State of Washington endangered species. Chelan rockmat, Sticky phacelia, and Dwarf evening-primrose are State of Washington threatened species.

5.2.11 Douglas Creek Dam and Reservoir Site

The Douglas Creek Dam and Reservoir site is located east of the Columbia River and north of the Moses Coulee, in south Douglas County near the border with Grant County (see Site 11 on Map 1). The Douglas Creek site exceeded the 10-mile limit from the Columbia River and 800-foot maximum pumping lift assumptions and was not evaluated in detail.

5.2.12 Sand Hollow Dam and Reservoir Site

5.2.12.1 Site Location

The Sand Hollow site is located east of the Columbia River, approximately 3.7 miles north of Wanapum Dam. The dam and reservoir would be located in southwest Grant County in Townships 16 and 17 North, Ranges 23, 24 and 25 East on the USGS 1:100,000 scale Priest Rapids, Washington topographic quadrangle (see Site 12 on Map 1). Map 14 shows the potential Sand Hollow Dam and Reservoir location in Grant County.

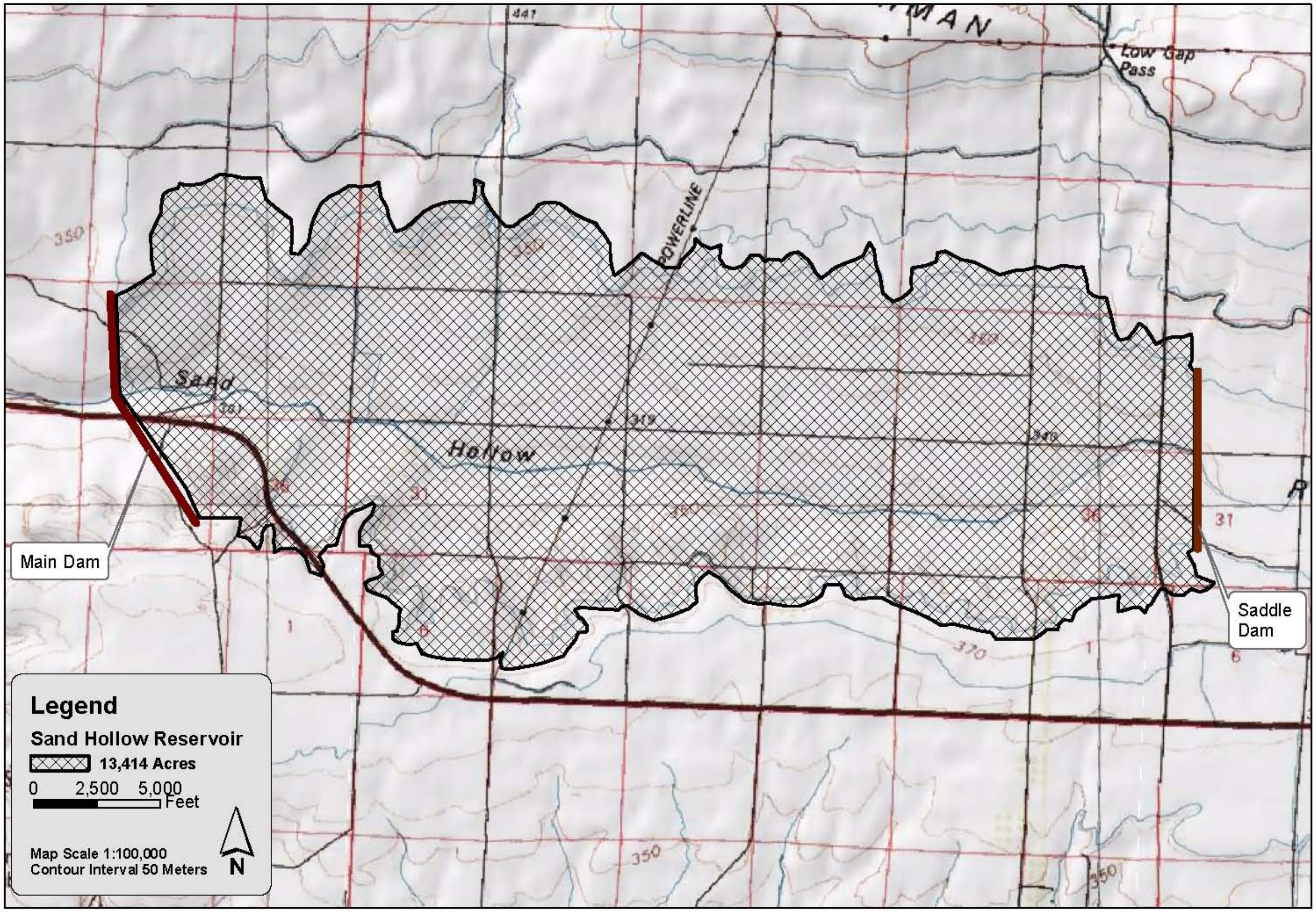
5.2.12.2 Previous Investigations

None identified.

5.2.12.3 Current Analysis

The Sand Hollow dam and reservoir site would have a full-pool elevation at 1,200 feet MSL and would inundate portions of the large low-relief Sand Hollow (see Map 15). Figure 5-19 shows the elevation-capacity-area curve for the potential Sand Hollow reservoir. Figure 5-20 shows a cross-section of the proposed dam site looking downstream.

Map 14
Sand Hollow Dam and Reservoir Location Map



Map 15
Sand Hollow Dam and Reservoir Site Map

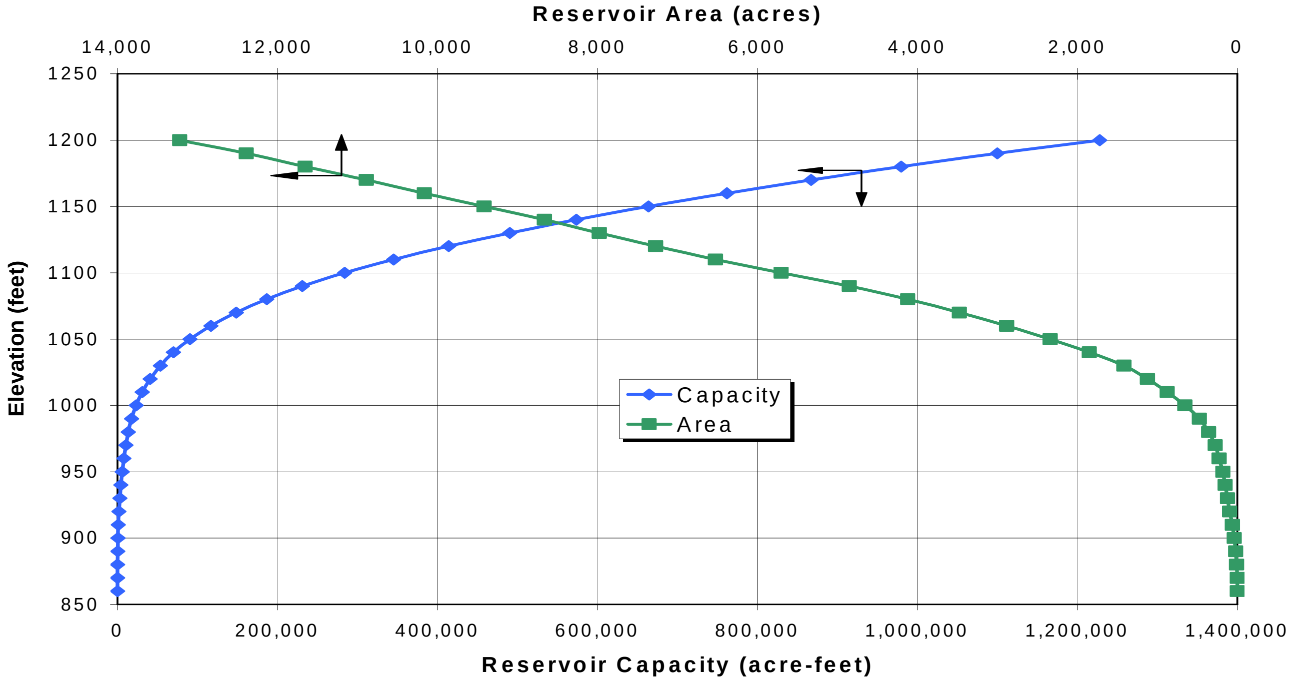


Figure 5-19. Sand Hollow Reservoir Elevation-Capacity-Area Curves

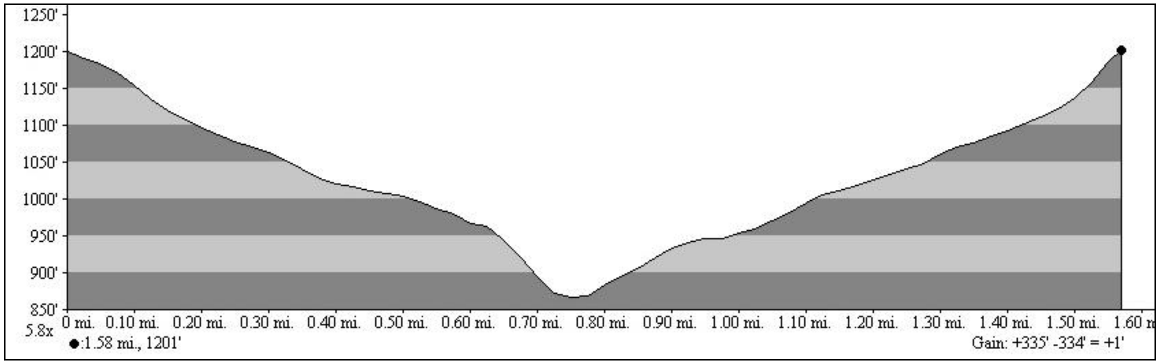


Figure 5-20. Sand Hollow Dam Cross Section

Reservoir Volume

Total potential storage volume is estimated at approximately 1,230,000 acre-feet. Usable storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 1,110,000 acre-feet. To achieve this volume, it would be necessary to construct a saddle dam at the east end of the reservoir approximately 7,000 feet long and 50 feet high at its maximum.

Inundated Area

The inundated surface area at full-pool elevation would be approximately 13,400 acres.

Dam Size

The dam would be located across a broad, gently sloping area at the western end of Sand Hollow. The dam would be approximately 10,000 feet long by 310 feet high, including a 10-foot freeboard (see Figure 5-20 for the dam cross section).

5.2.12.4 Water Sources and Availability

The Sand Hollow Reservoir would have a drainage area of about 50 square miles. The average annual inflow at the dam site would be roughly on the order of about 30,000 ac-ft per year. This inflow is minor in comparison to the potential reservoir capacity, and it is insignificant in comparison to the more than 20,000,000 acre-feet of water that would be available for pumping from the Columbia River. The diversion point would be in Wanapum Lake, which is impounded by Wanapum Dam. Water availability at Wanapum Dam is essentially the same as for Rock Island Dam. Water availability for Rock Island Dam was previously presented in section 5.2.10.4 for the Moses Coulee Dam and Reservoir.

5.2.12.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Sand Hollow Dam and Reservoir is shown in Table 5-23.

Table 5-23. Pre-Appraisal-Level Cost Estimate for Sand Hollow Dam and Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	236,000,000	
2. Spillway/Outlet Works	25,000,000	
3. Pumping Plant, Pumps & Motors	206,000,000	
4. Waterway (tunnel)	69,000,000	
Sub-Total (Field Costs)	536,000,000	
Allowances		
Mobilization (5% x Field Costs)	26,800,000	
Sub-Total (Field Costs plus Mobilizaton)	562,800,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	84,420,000	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	647,220,000	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	161,805,000	
Direct Construction Costs	809,025,000	
Indirect Costs (20% to 35% of Direct Construction Costs)	161,805,000	283,158,750
Range Totals	**970,830,000**	**1,092,183,750**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.12.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Sand Hollow Reservoir could be used to supplement Columbia River instream flows for anadromous fish and could be released during April through August when 2000 BiOp target flows are not met at McNary Dam. The Sand Hollow Reservoir would store enough water to meet a range of 12 to 37 percent of the 2000 BiOp target flows at McNary Dam during a one-month period from April through August based on monthly average flows at Grand Coulee, Priest Rapids and Bonneville dams.

Agricultural Irrigation

An arbitrary distance of 50 miles for conveyance of stored water was used to estimate potential agricultural use. Beyond this distance, conveyance costs would make agricultural use uneconomical. Most of Grant (446,183 irrigated acres - IA) and parts of Douglas (21,199 IA), Kittitas (75,859 IA), Yakima (277,389 IA), Benton (153,254 IA), Adams (148,018 IA) and Franklin (221,245 IA) Counties lie within the 50-mile range for irrigation water. The Sand Hollow site could be a significant resource for agricultural irrigation in a seven-county area.

M&I Water Supply

There could be future potential benefits from using Sand Hollow storage water for an M&I water supply. The large population centers of note within a 50-mile radius of the site would be the Richland/Pasco/Kennewick metro area and the City of Yakima and the smaller communities of Moses Lake (pop. 14,953) and Othello (pop. 5,847). Local water supplies are expected to be sufficient to continue meeting near term M&I water supply needs, but the Sand Hollow Reservoir could meet future needs due to expected growth of those communities.

Recreation

There would be some opportunities for recreational boating on the potential Sand Hollow reservoir. Development of a fishing resource would require fish stocking and fisheries management in the potential reservoir.

5.2.12.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.12.8 Regional and Local Geology

The Sand Hollow site is located east of the Columbia River, in the west part of the Columbia Plateau, a structural and topographic basin, which encompasses most of the Columbia River drainage. Exposed rock at this site is the middle to upper Miocene Wanapum Basalt, which is 200 to 300 feet thick in this vicinity and may consist of multiple individual flows (Drost and Whiteman, 1986). Contacts between individual flows in the Wanapum Basalt are sometimes rubbly and fractured, and these contact zones tend to be zones of higher permeability. Exposed rock outcrops are generally unweathered. Overburden consists of Quaternary alluvial deposits that are less than 50 feet thick and are comprised primarily of silt, fine sand, and silty sand, although some gravelly and cobbly sands are present (Swanson et al., 1979; NRCS, 1984). Sand Hollow lies within the Yakima Fold Belt Subprovince and is located between the east-west trending Frenchman Hills Anticline and Saddle Mountain Anticline. A cluster of transverse faults lies approximately 10 to 20 miles west of the site. A short thrust fault is located in the Frenchman Hills Anticline approximately 10 miles north of the site (Drost and Whiteman, 1986).

5.2.12.9 Potential Environmental and Institutional Issues

The dam and reservoir area is located in Water Resource Inventory Area (WRIA) #41. There would be no direct long-term impacts on anadromous fish populations from construction and operation of a dam and reservoir at this site. The dam would be located approximately 1.2 miles upstream of a culvert under State Highway 26, which is a barrier to anadromous fish passage (WRIA #41, 2005).

There are no major structures in the Sand Hollow potential reservoir area. Portions of State Highway 26 and local roads would be inundated. A transmission line crosses the eastern end of the potential reservoir and may need to be relocated. The area within the potential reservoir site is extensively cropped. There are no wildlife refuges designated in the potential reservoir area. The reservoir would inundate approximately 69 acres of NWI wetlands at full pool elevation.

The Washington State GAP Analysis database (WAGAP 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with predicted habitat or recorded occurrences in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. Habitat in the Sand Creek site is almost entirely in agriculture - irrigated row crops and extensive crop circles. Table 5-24 summarizes listed vertebrate species that have potential habitat in the area of the potential Sand Hollow dam and reservoir site.

Table 5-24. Listed Vertebrate Species With GAP Habitat in the Sand Hollow Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Northern leopard frog	*Rana pipiens*	NL	SE
Sagebrush lizard	*Sceloporus graciosus*	NL	SC
Striped whipsnake	*Masticophis taeniatus*	NL	SC
Burrowing owl	*Athene cunicularia*	NL	SC
Ferruginous Hawk	*Buteo regalis*	NL	ST
Loggerhead shrike	*Lanius ludovicianus*	NL	SC
Sage sparrow	*Amphispiza belli*	NL	SC
Sage thrasher	*Oreoscoptes montanus*	NL	SC
Black-tailed jack rabbit	*Lepus californicus*	NL	SC
Merriam’s shrew	*Sorex merriamii*	NL	SC
Townsend’s big-eared bat	*Coryhorhinus townsendii*	NL	SC
Washington ground squirrel	*Spermophilus washingtoni*	C	SC
White-tailed jack rabbit	*Lepus townsendii*	NL	SC

Notes:
[1] NL = Not Listed; C = Candidate
[2] SC = State Candidate; ST = State Threatened; SE = State Endangered

Sand Hollow is less than four miles north of Crab Creek across a low ridge. The natural habitat in the Sand Hollow potential reservoir area has been largely converted to irrigated agriculture and the habitat values for many species have been changed. However, because of the proximity of the sites, the vertebrate species list and impacts were assumed to be the same as Crab Creek.

Because Sand Hollow has been extensively cultivated for agriculture, it was assumed that there is no habitat for potential listed plant species in the potential reservoir area.

5.2.12.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Sand Hollow site would involve the following environmental and institutional issues of concern:

- Approximately 69 acres of NWI wetlands would be impacted, requiring a Clean Water Act Section 404 permit and mitigation.
- Portions of State Highway 26 would be inundated by the reservoir.
- Local roads would be inundated by the reservoir.
- Power transmission line facilities would be inundated by the reservoir.
- Extensive agricultural land (irrigated crops) would be inundated by the reservoir.
- Farm structures would be inundated by the reservoir.
- Washington ground squirrel, a federal candidate species, has suitable habitat within the reservoir area.
- Northern leopard frog, a State of Washington-listed endangered species, has been observed in the reservoir area and suitable habitat would be inundated by the reservoir.
- Ferruginous hawk, a State of Washington threatened species, has been observed in the area and suitable habitat may inundated by the reservoir.

5.2.13 Crab Creek Dam and Reservoir Site

5.2.13.1 Site Location

The Crab Creek site is located east of the Columbia River, approximately four miles south of Wanapum Dam. The dam and reservoir would be located in southwest Grant County in Township 16 North, Ranges 23, 24, 25 26, 27 and 28 East on the USGS 1:100,000 scale Priest Rapids, Washington topographic quadrangle (see Site 13 on Map 1). Map 16 shows the potential Crab Creek Dam and Reservoir location in Grant County.

5.2.13.2 Previous Investigations

None identified.

5.2.13.3 Current Analysis

The Crab Creek dam and reservoir site would have a full-pool elevation at 700 feet MSL and would inundate portions of the large low-relief Lower Crab Creek drainage (see Map 17). Figure 5-21 shows the elevation-capacity-area curve for the potential Crab Creek reservoir. Figure 5-22 shows a cross-section of the proposed dam site looking downstream.

Reservoir Volume

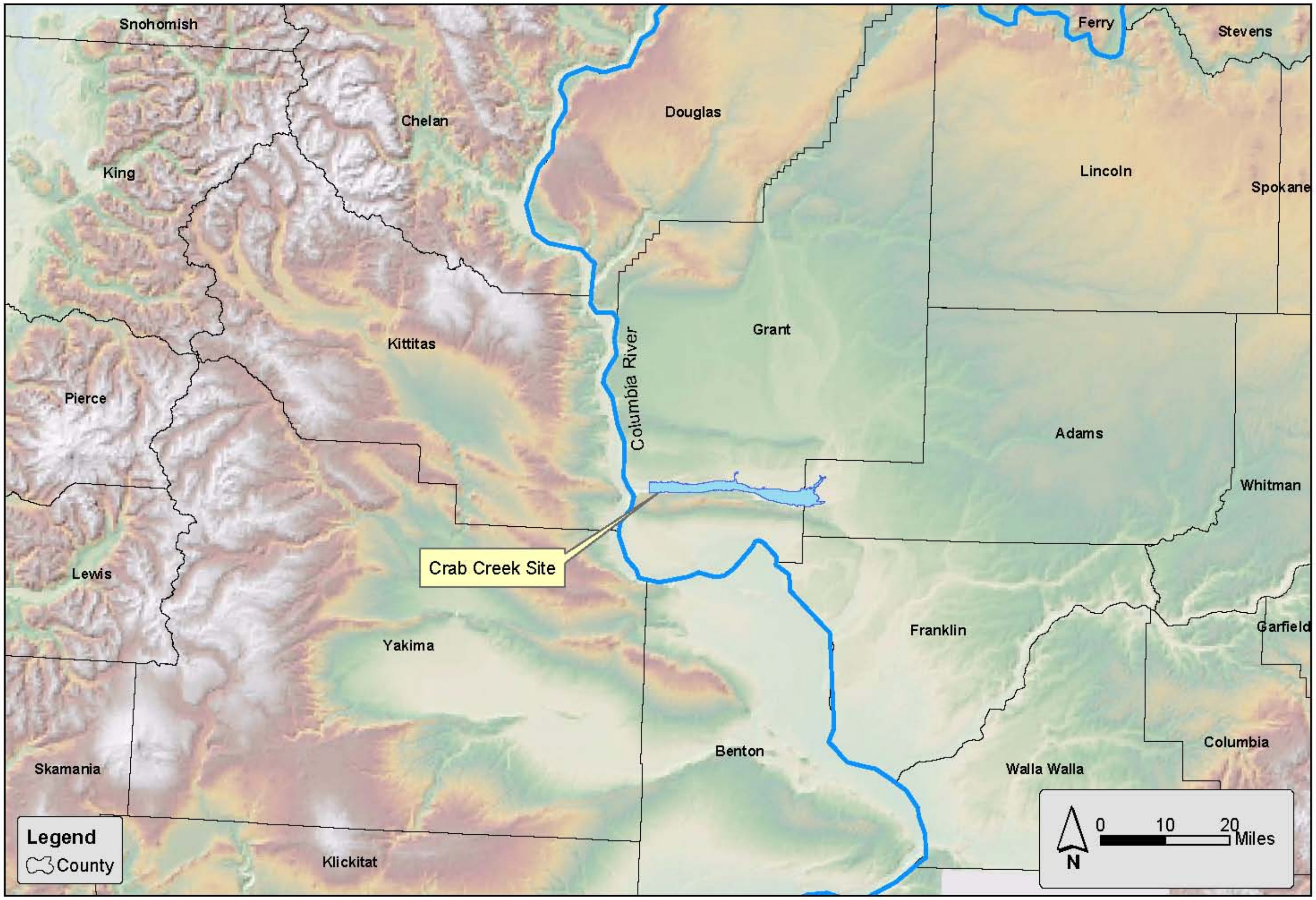
Total potential storage volume is estimated at approximately 2,650,000 acre-feet. Usable storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 2,390,000 acre-feet.

Inundated Area

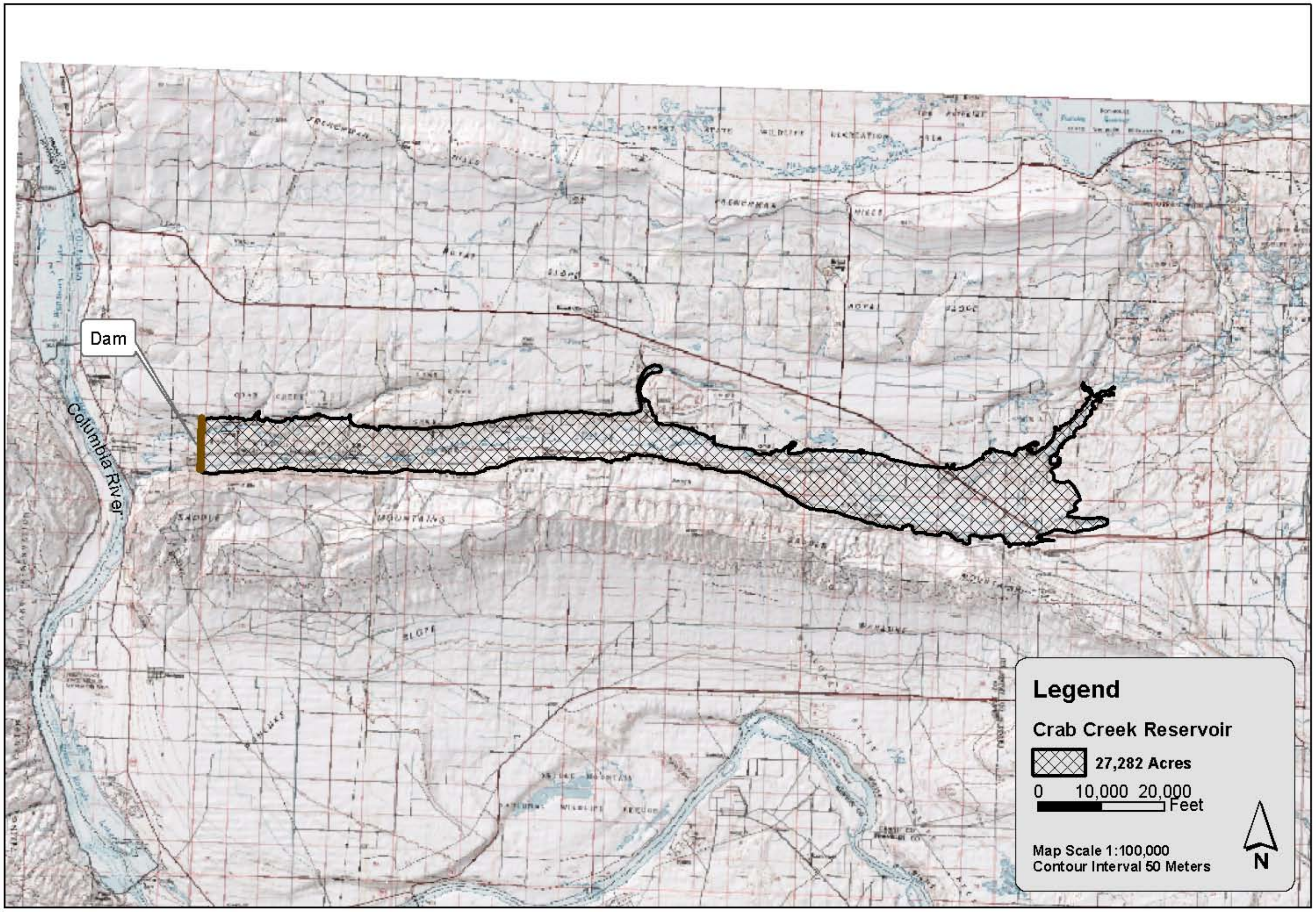
The inundated surface area at full-pool elevation would be approximately 27,300 acres in a shallow narrow reservoir approximately 26 miles long.

Dam Size

The dam would be approximately 8,400 feet long by 200 feet high, including a 10-foot freeboard (see Figure 5-22 for the dam cross section).



Map 16
Crab Creek Dam and Reservoir Location Map



Map 17
Crab Creek Dam and Reservoir Site Map

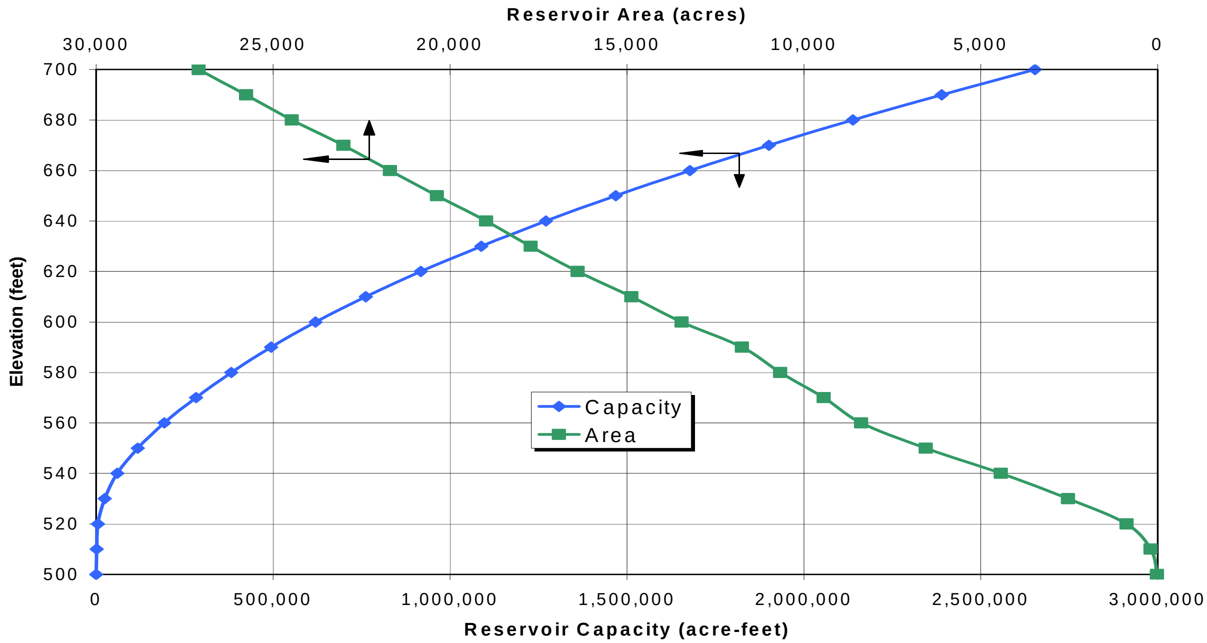


Figure 5-21. Crab Creek Reservoir Elevation-Capacity-Area Curves

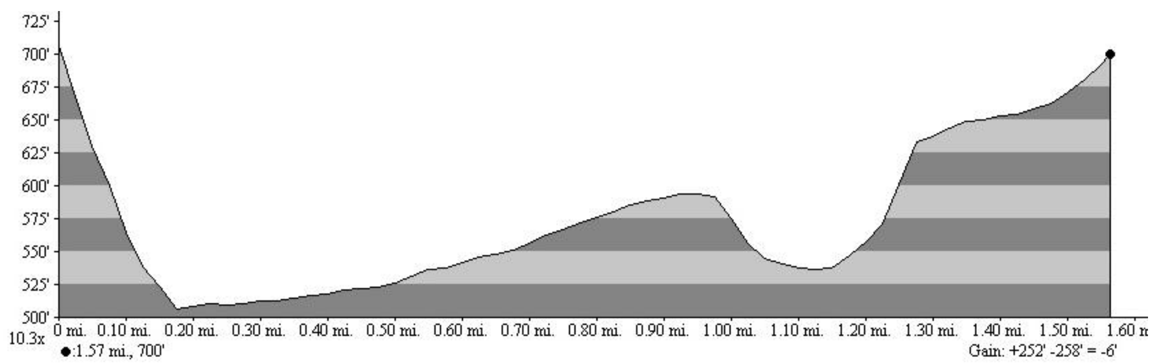


Figure 5-22. Crab Creek Dam Cross Section

5.2.13.4 Water Sources and Availability

The Crab Creek Reservoir would have a large drainage area of about 4,000 square miles. Lower Crab Creek is the outlet stream for Potholes Reservoir, which is impounded by O'Sullivan Dam. Flows in lower Crab Creek are predominantly return flows from the Columbia Basin Project. Because the area is very arid, the average annual inflow at the dam site would be relatively low on a runoff per unit area basis and would vary substantially from year to year. Average Crab Creek inflow to the reservoir would be on the order of about 30,000 acre-feet per year based on flow data at a USGS gaging station that was located on Crab Creek about 15 miles upstream from the confluence with the Columbia River. This inflow is minor in comparison to the potential reservoir capacity, and it is insignificant in comparison to the more than 20,000,000 acre-feet of water that would be available for pumping from the Columbia River. The diversion point could be in the reservoir impounded either by Wanapum Dam or Priest Rapids Dam. For this analysis, the diversion point will be assumed to be in Priest Rapids Lake. The total flow of the Columbia River at Priest Rapids Dam is presented in Table 5-25.

Table 5-25. Total Columbia River Flow at Priest Rapids Dam (1000's of acre-feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	4,769	5,745	5,687	6,626	3,610	3,997	1,934	1,934	3,997	6,412	6,890	3,289	3,059	3,913	61,860
1930	5,226	6,113	5,657	4,304	3,888	4,304	2,083	2,083	4,328	7,616	7,352	3,697	3,396	4,107	64,151
1931	4,969	5,911	6,124	3,997	3,610	3,997	1,934	1,934	5,335	7,656	6,411	3,832	3,357	4,368	63,435
1932	5,048	5,702	6,044	3,997	3,610	3,997	3,416	5,291	10,874	10,244	8,403	4,426	4,013	4,073	79,137
1933	4,833	5,032	6,874	9,714	7,949	3,834	2,432	3,193	9,593	13,620	14,013	4,505	4,873	4,626	95,091
1934	6,240	7,322	10,825	14,381	10,382	7,782	5,664	6,570	13,714	7,806	8,701	3,294	2,875	4,002	109,557
1935	4,925	5,154	6,205	9,537	8,943	3,689	2,544	3,542	8,850	9,565	9,228	4,588	3,392	4,152	84,315
1936	5,049	5,806	6,147	4,533	3,610	3,997	1,934	2,203	12,475	8,687	6,844	3,923	3,094	3,712	72,014
1937	5,044	5,927	6,029	4,604	3,888	4,304	2,083	2,083	4,304	6,700	6,484	3,677	2,901	3,802	61,829
1938	5,210	5,434	5,096	10,076	5,009	5,901	2,826	3,743	12,596	8,440	7,868	3,235	2,645	4,133	82,211
1939	4,871	5,568	5,246	7,071	3,730	3,997	1,934	2,493	9,519	7,256	6,779	4,100	3,190	3,782	69,535
1940	5,193	5,739	6,003	6,258	4,042	5,858	2,369	3,453	7,640	8,123	6,123	3,444	3,016	3,652	70,913
1941	4,851	5,173	6,085	6,836	3,332	4,293	1,864	2,407	5,952	7,192	5,259	3,194	3,050	3,910	63,398
1942	4,696	4,794	7,299	9,930	3,891	3,382	1,717	2,609	7,289	10,082	9,199	4,572	3,800	3,858	77,117
1943	5,014	5,149	5,308	7,700	5,233	5,503	4,462	4,610	13,016	10,122	9,257	4,396	3,824	3,785	87,379
1944	4,840	5,591	5,145	7,087	3,610	3,997	1,934	1,934	4,661	6,349	5,142	3,356	2,816	4,007	60,467
1945	4,844	5,799	6,047	3,997	3,610	3,997	1,934	1,934	6,477	9,356	7,031	3,425	3,286	3,588	65,324
1946	5,072	5,544	4,687	6,251	5,682	6,250	3,249	4,403	13,878	10,396	9,497	4,593	3,745	4,177	87,425
1947	4,441	5,068	7,319	9,270	6,213	7,634	2,618	4,286	11,333	9,772	9,006	4,535	3,182	4,010	88,686
1948	7,375	6,413	7,235	8,761	4,306	5,397	2,937	4,329	12,742	23,653	10,872	4,606	5,047	5,199	108,872
1949	5,195	5,368	6,022	7,372	4,771	6,844	2,130	5,203	12,146	10,106	6,510	3,434	2,675	3,478	81,255
1950	4,871	5,465	5,031	7,909	7,478	8,317	3,526	4,512	11,941	15,890	10,768	4,366	4,499	4,433	99,005
1951	5,676	6,451	8,714	11,335	9,376	6,726	3,678	5,364	15,691	9,000	10,621	4,640	4,386	4,689	106,347
1952	6,506	5,636	7,123	9,250	5,635	6,405	3,262	4,237	13,647	8,796	7,611	4,289	3,088	3,786	89,270
1953	4,804	5,825	5,632	5,474	6,648	4,003	1,934	3,011	10,875	11,967	10,204	4,488	3,597	4,158	82,621
1954	5,129	5,561	6,847	8,032	7,246	6,351	3,452	3,176	12,923	16,458	12,626	5,644	4,997	7,725	106,167
1955	5,836	6,486	7,520	6,145	4,032	4,304	2,083	2,083	6,986	16,715	15,378	4,754	4,987	4,309	91,617
1956	5,653	6,428	8,058	11,385	5,770	7,142	4,087	6,233	16,435	15,468	11,302	4,568	4,125	4,148	110,802
1957	5,106	5,242	6,632	8,538	3,999	4,301	3,933	3,635	12,219	13,724	7,841	3,609	2,965	3,787	85,531
1958	4,754	5,554	5,061	7,358	5,680	6,279	2,205	3,826	11,562	11,196	6,995	3,633	3,242	3,929	81,274
1959	4,776	5,677	7,295	10,961	8,000	5,843	3,853	4,142	12,187	13,831	12,211	4,720	4,000	7,256	104,752
1960	8,075	7,430	9,053	9,368	4,931	5,254	5,545	4,984	10,168	10,518	9,776	4,822	3,119	4,112	97,155
1961	5,005	5,512	6,321	8,902	6,539	6,455	4,136	4,331	11,219	17,534	8,589	3,971	3,659	3,657	95,827
1962	4,783	5,328	5,032	8,292	3,736	3,997	4,202	4,643	9,725	8,132	9,013	4,234	3,676	3,790	78,583
1963	4,969	5,903	7,485	8,461	4,169	5,659	2,201	2,974	9,335	8,305	9,068	4,657	3,609	4,279	81,074
1964	4,622	5,379	5,896	8,306	5,152	3,997	1,934	3,542	8,815	14,012	13,605	4,714	4,356	4,930	89,259
1965	6,124	5,603	7,576	11,203	7,324	6,846	3,183	4,643	12,203	9,932	8,179	4,585	4,156	3,940	95,497
1966	4,961	5,669	6,725	8,975	4,716	4,058	3,545	3,347	9,867	8,828	10,222	4,900	3,812	3,861	83,487
1967	4,726	5,521	6,060	9,892	8,784	5,700	3,609	3,896	8,582	15,403	12,427	4,689	4,109	4,481	97,878
1968	4,975	5,662	6,659	8,893	5,961	6,251	1,934	3,323	8,077	10,908	11,664	4,806	4,165	5,564	88,842
1969	5,866	6,181	7,421	10,210	7,376	5,348	5,090	5,102	14,854	10,900	9,005	4,458	3,184	3,892	98,889
1970	4,835	5,788	5,921	7,424	5,491	4,304	2,083	3,807	7,938	10,019	6,251	3,324	2,886	3,251	73,320
1971	4,567	5,399	4,500	8,483	9,128	5,868	3,153	4,591	15,559	12,995	10,828	4,640	4,848	4,065	98,624
1972	4,540	4,988	6,219	8,718	8,855	9,228	5,905	4,090	14,892	18,649	13,426	5,314	5,046	4,694	114,564
1973	4,927	5,193	6,301	8,779	3,597	4,007	1,785	2,198	5,583	7,583	6,577	3,452	2,810	3,262	66,054
1974	4,682	4,281	7,076	13,341	10,538	7,352	4,431	5,494	14,683	16,144	14,819	4,722	4,991	4,786	117,341
1975	4,531	5,403	5,390	8,416	5,605	6,548	2,538	3,417	10,558	10,770	11,720	3,623	3,069	4,074	85,662
1976	5,270	6,564	9,368	10,491	7,922	5,230	4,314	4,470	13,365	8,481	12,394	5,981	5,849	8,376	108,075
1977	5,135	5,679	5,346	7,254	3,610	3,997	1,934	1,934	6,507	6,363	5,223	3,696	2,897	3,704	63,278
1978	4,320	5,065	4,242	6,957	3,752	7,271	3,150	4,151	10,805	8,611	9,290	4,148	3,627	4,841	80,230
Average	5,155	5,664	6,432	8,221	5,679	5,400	3,014	3,708	10,358	10,926	9,290	4,231	3,700	4,322	86,100
Maximum	8,075	7,430	10,825	14,381	10,538	9,228	5,905	6,570	16,435	23,653	15,378	5,981	5,849	8,376	117,341
Minimum	4,320	4,281	4,242	3,997	3,332	3,382	1,717	1,934	3,997	6,349	5,142	3,194	2,645	3,251	60,467

Water availability for diversion to an offstream storage site from the pool behind Priest Rapids Dam has been previously determined by the U.S. Bureau of Reclamation (USBR, 2004). The water availability from Priest Rapids Lake to the Crab Creek Reservoir is presented in Table 5-26.

Table 5-26. Total Water Availability in Priest Rapids Lake (1000's of acre-feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	1,387	0	0	1,286	0	0	0	0	0	0	0	0	0	640	3,313
1930	1,844	0	0	0	373	0	0	0	0	0	0	0	0	834	3,051
1931	1,587	0	0	0	0	0	0	0	0	0	0	0	0	1,095	2,682
1932	1,666	0	0	0	0	2,274	608	971	2,552	234	216	0	0	801	9,322
1933	1,451	0	1,537	5,222	3,289	0	0	0	0	5,587	5,137	0	0	1,419	23,642
1934	2,858	2591	9,752	13,415	7,578	4,848	2,808	927	757	0	0	0	0	729	46,263
1935	1,543	0	963	4,611	4,831	0	0	0	0	0	26	0	0	879	12,853
1936	1,667	0	0	0	0	123	0	0	3,883	0	0	0	0	440	6,113
1937	1,662	0	0	0	0	0	0	0	0	0	0	0	0	530	2,192
1938	1,828	0	829	5,977	920	3,548	59	0	3,644	0	0	0	0	860	17,665
1939	1,490	0	0	1,903	0	347	0	0	0	0	0	0	0	509	4,249
1940	1,811	0	324	1,010	177	3,441	0	0	0	0	0	0	0	380	7,143
1941	1,470	0	1,013	2,094	0	0	0	0	0	0	0	0	0	637	5,214
1942	1,314	0	3,706	5,673	260	0	0	0	0	171	463	0	0	585	12,172
1943	1,632	0	1,387	4,996	3,709	4,074	1,784	593	3,516	1,462	2,075	0	0	512	25,740
1944	1,458	0	89	1,731	0	0	0	0	0	0	0	0	0	734	4,012
1945	1,462	0	0	0	0	0	0	0	0	0	0	0	0	315	1,777
1946	1,690	0	231	3,133	2,148	4,239	482	39	4,457	0	857	0	0	904	18,180
1947	1,060	0	5,174	5,675	4,199	4,367	0	0	2,363	0	236	0	0	737	23,811
1948	3,993	1699	2,887	6,072	1,220	2,026	81	0	4,311	15,620	2,691	0	0	1,927	42,527
1949	1,814	0	955	2,297	1,540	6,525	0	695	3,846	0	0	0	0	205	17,877
1950	1,490	0	156	3,091	5,026	7,537	759	281	1,790	7,856	3,747	0	0	1,161	32,894
1951	2,294	2627	6,406	9,109	8,943	5,173	1,000	1,050	6,410	0	1,613	0	0	1,416	46,041
1952	3,124	412	3,340	4,990	3,232	2,978	405	220	5,279	0	0	0	0	513	24,493
1953	1,422	0	0	2,958	4,782	184	0	0	562	3,934	1,955	0	0	885	16,682
1954	1,747	81	2,368	4,107	4,813	2,541	685	0	3,173	6,281	3,923	952	0	4,452	35,123
1955	2,454	1170	2,056	1,044	0	0	0	0	0	7,265	6,264	0	0	1,037	21,290
1956	2,271	1976	6,450	10,088	3,284	6,679	1,409	2,216	8,067	7,435	2,711	0	0	875	53,461
1957	1,725	0	2,704	3,533	0	2,546	1,255	0	3,918	5,691	0	0	0	514	21,886
1958	1,373	0	398	3,136	3,955	2,876	0	0	3,131	1,951	0	0	0	657	17,477
1959	1,394	1019	3,747	8,782	5,011	2,609	1,175	0	1,410	5,052	3,306	0	0	3,984	37,489
1960	4,694	3082	4,817	4,475	1,360	2,090	2,689	200	0	481	372	0	0	839	25,099
1961	1,623	553	964	3,981	4,979	3,993	1,372	0	389	8,332	0	0	0	384	26,570
1962	1,401	0	59	3,733	0	0	1,484	626	0	0	0	0	0	517	7,820
1963	1,587	1047	3,703	3,899	2,543	1,211	0	0	0	0	41	0	0	1,006	15,037
1964	1,240	0	375	3,641	660	0	0	0	0	5,979	4,743	0	0	1,657	18,295
1965	2,743	159	7,388	10,836	8,165	5,171	327	626	3,835	1,899	243	0	0	667	42,059
1966	1,579	223	1,993	4,767	0	92	683	0	0	0	698	0	0	589	10,624
1967	1,344	0	1,184	5,768	5,984	650	842	0	0	7,189	3,661	0	0	1,208	27,830
1968	1,593	220	2,042	4,925	4,216	2,446	0	0	0	896	2,701	0	0	2,291	21,330
1969	2,484	1528	2,892	8,023	4,813	3,118	2,412	1,086	6,486	629	185	0	0	619	34,275
1970	1,454	0	530	5,392	3,648	497	0	0	0	1,986	0	0	0	0	13,507
1971	1,185	0	452	7,606	9,358	4,092	564	455	7,128	4,962	3,308	0	0	792	39,902
1972	1,158	103	2,025	6,758	8,114	13,880	3,228	0	6,524	10,616	4,977	529	0	1,421	59,333
1973	1,545	0	2,564	5,537	0	0	0	0	0	0	0	0	0	0	9,646
1974	1,300	0	4,814	13,853	9,371	6,685	1,932	1,477	6,253	8,111	7,671	129	0	1,513	63,109
1975	1,150	0	800	5,056	2,478	3,927	0	0	2,225	2,737	5,096	0	0	801	24,270
1976	1,888	2160	8,488	8,839	5,041	3,371	1,637	335	4,934	106	3,843	1,453	0	5,103	47,198
1977	1,753	0	313	1,936	0	0	0	0	0	0	0	0	0	431	4,433
1978	938	0	2,243	3,743	1,318	4,746	473	0	1,584	0	1,131	0	0	1,036	17,212
Average	1,773	413	2,082	4,574	2,827	2,498	603	236	2,049	2,449	1,478	61	0	1,041	22,084
Maximum	4,694	3,082	9,752	13,853	9,371	13,880	3,228	2,216	8,067	15,620	7,671	1,453	0	5,103	63,109
Miniumum	938	0	0	0	0	0	0	0	0	0	0	0	0	0	1,777
# Years of Avail. Water	50	17	41	44	35	35	25	16	27	26	29	4	0	48	50

5.2.13.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Crab Creek Dam and Reservoir is shown in Table 5-27.

Table 5-27. Pre-Appraisal-Level Cost Estimate for Crab Creek Dam and Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	$ 588,000,000	
2. Spillway/Outlet Works	$ 60,000,000	
3. Pumping Plant, Pumps & Motors	$ 195,000,000	
4. Waterway (tunnel)	$ 97,000,000	
Sub-Total (Field Costs)	$ 940,000,000	
Allowances		
Mobilization (5% x Field Costs)	$ 47,000,000	
Sub-Total (Field Costs plus Mobilizaton)	$ 987,000,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	$ 148,050,000	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	$ 1,135,050,000	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	$ 283,762,500	
Direct Construction Costs	$ 1,418,812,500	
Indirect Costs (20% to 35% of Direct Construction Costs)	$ 283,762,500	$ 496,584,375
Range Totals	**$ 1,702,575,000**	**$ 1,915,396,875**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.13.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Crab Creek Reservoir could be used to supplement Columbia River instream flows for anadromous fish and could be released during April through August when 2000 BiOp target flows are not met at McNary Dam. The Crab Creek Reservoir would store enough water to meet a range of 26 to 79 percent of the 2000 BiOp target flows at McNary Dam during a one-month period from April through August based on monthly average flows at Grand Coulee, Priest Rapids and Bonneville dams.

Agricultural Irrigation

An arbitrary distance of 50 miles for conveyance of stored water was used to estimate potential agricultural use. Beyond this distance, conveyance costs would make agricultural use uneconomical. Most of Grant (446,183 irrigated acres - IA) and parts of Douglas (21,199 IA), Kittitas (75,859 IA), Yakima (277,389 IA), Benton (153,254 IA), Adams (148,018 IA) and Franklin (221,245 IA) counties lie within the 50-mile range for irrigation water. The Crab Creek site could be a significant resource for agricultural irrigation in a seven-county area.

M&I Water Supply

There could be future potential benefits from using Crab Creek storage water for an M&I water supply. The large population centers of note within a 50-mile radius of the site would be the Pasco/Kennewick/Richland metro area and the City of Yakima and the smaller communities of Moses Lake (pop. 14,953) and Othello (pop. 5,847). Local water supplies are expected to be sufficient to continue meeting near-term M&I water supply needs, but the Crab Creek Dam and Reservoir could meet long-term water needs for future growth of those communities.

Recreation

There would be some opportunities for recreational boating on the potential Crab Creek reservoir. Development of a fishing resource would require fish stocking and fisheries management in the potential reservoir. If a fish ladder were included in the dam, there would be a steelhead fishery resource in the reservoir and upstream tributaries.

5.2.13.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.13.8 Regional and Local Geology

The Crab Creek site is located in the western part of the Columbia Plateau, a structural and topographic basin that encompasses most of the Columbia River drainage. Exposed bedrock at this site are basalts of the Columbia River Basalt Group and include, from lower to higher elevation, the lower Miocene Grande Ronde Basalt, the overlying middle to upper Miocene Wanapum Basalt, and the upper Miocene Saddle Mountains Basalt. Both the Grande Ronde and Wanapum basalts consist of multiple flows with rare sedimentary interbeds. The Grande Ronde Basalt may be several thousand feet thick at this location. The Wanapum Basalt is approximately 800 feet thick at this location. The Saddle Mountains Basalt contains frequent sedimentary interbeds that may be from a few inches to several feet thick. Where present, the Saddle Mountains Basalt is probably from 0 to about 100 feet thick at this location (Drost and Whiteman, 1986). Exposed rock outcrops of all basalt units are not extensively weathered. Contacts between individual flows in both the Grande Ronde and Wanapum basalts are sometimes rubbly and fractured, and these contact zones tend to be zones of higher permeability. The contact between the Grande Ronde and Wanapum basalts often is divided by the Vantage Member of the Ellensburg Formation (typically expressed as a siltstone or tuffaceous conglomerate). If present at this location, it is probably only a few feet thick. Between the Wanapum Basalt and Saddle Mountains Basalt, an interbed informally designated the Mabton Member of the Ellensburg Formation is probably present but may be only a few feet thick.

This interbed typically consists of silt or clay but sometimes includes sand and gravel (Drost and Whiteman, 1986; Swanson et al., 1979). Approximately 50 to 100 feet of sedimentary overburden, mostly fine sand but also including silt, coarse sand, and gravel, overlies the valley floor (Drost and Whiteman, 1986; NRCS, 1984). The site overlies the Saddle Mountains Anticline, a major east-west trending feature of the Yakima Fold Belt. A thrust fault associated with the anticline runs parallel to Crab Creek near the axis of the anticline (Drost and Whiteman, 1986).

5.2.13.9 Potential Environmental and Institutional Issues

The dam and reservoir area is located in Water Resource Inventory Area (WRIA) #41. Crab Creek had been listed as a Section 303(d) stream in 1996, but was removed in 1998 because of only single values beyond criteria (WRIA 41, 2005). Crab Creek was not listed for water quality violations in the 2003 Washington State surface water quality report (Ecology, 2004). Crab Creek is used by steelhead trout (WRIA 41, 2005). The proposed dam would be a barrier to steelhead passage unless a fish ladder were constructed at the dam.

There are no major structures in the Crab Creek potential reservoir area. An abandoned Chicago, Milwaukee, St. Paul and Pacific Railroad track parallels Crab Creek and would be inundated by the reservoir. There are no major road corridors in the reservoir area and only local roads would be inundated, including Lower Crab Creek County Road. A transmission line follows Crab Creek in the potential reservoir and would need to be relocated. There are areas within the potential reservoir site that are cropped.

The Crab Creek drainage contains portions of the Columbia National Wildlife Refuge and the Lower Crab Creek State Wildlife Area. The potential reservoir would inundate the existing Nunnally, Merry and Lenice Lakes and multiple unnamed ponds and wetlands. The reservoir would inundate approximately 18,663 acres of NWI wetlands at full pool elevation. The area is a breeding and migration resource for large numbers of waterfowl and shorebirds.

The Washington State GAP Analysis database (WAGAP, 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with predicted habitat or recorded occurrences in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. Habitat in the Crab Creek site is a mixture of irrigated cropland and marshlands surrounded by and interspersed with dry grasslands. Table 5-28 summarizes listed vertebrate species that have potential habitat in the area of the potential Crab Creek dam and reservoir site.

Table 5-28. Listed Vertebrate Species With GAP Habitat in the Crab Creek Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Northern leopard frog	*Rana pipiens*	NL	SE
Sagebrush lizard	*Sceloporus graciosus*	NL	SC
Striped whipsnake	*Masticophis taeniatus*	NL	SC
Burrowing owl	*Athene cunicularia*	NL	SC
Ferruginous Hawk	*Buteo regalis*	NL	ST
Loggerhead shrike	*Lanius ludovicianus*	NL	SC
Sage sparrow	*Amphispiza belli*	NL	SC
Sage thrasher	*Oreoscoptes montanus*	NL	SC
Black-tailed jack rabbit	*Lepus californicus*	NL	SC
Merriam's shrew	*Sorex merriamii*	NL	SC
Townsend's big-eared bat	*Coryhorhinus townsendii*	NL	SC
Washington ground squirrel	*Spermophilus washingtoni*	C	SC
White-tailed jack rabbit	*Lepus townsendii*	NL	SC

Notes:
[1] NL = Not Listed; C = Candidate
[2] SC = State Candidate; ST = State Threatened; SE = State Endangered

Small animals with limited dispersal capacity and home ranges impacted by dam construction or inundated by the reservoir would be at greatest risk. Large mobile species and birds could disperse from the construction and inundation zones. Bats would generally not be impacted unless a dam or reservoir would cover or inundate a hibernaculum. Sagebrush lizard and striped whipsnake have potential habitat in the area of the reservoir, but no observations; northern leopard frog habitat borders the east end of the potential reservoir. There are observations of breeding occurrences for burrowing owl and loggerhead shrike and possible breeding of sage sparrow and sage thrasher; the other bird species have potential habitat present without observations. Black-tailed jack rabbits have been observed within the site and have potential habitat in the area of the reservoir. Potential habitat for white-tailed jack rabbit is marginal. Washington gray squirrel has potential habitat in the eastern reservoir area, but does not have recorded occurrences.

A number of listed plant species have been located near the Crab Creek site by the Washington Natural Heritage Program (WNHP, 2005). The scale of the mapping does not allow a definitive inclusion/exclusion of these species and, if the site is considered for development, a specific inventory should be performed. The potential listed plant species are summarized in Table 5-29.

Table 5-29. Listed Plant Species in the Crab Creek Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Northern wormwood	*Artemesia campestris ssp. Borealis var. wormskioldii*	C	E
Columbia milkvetch	*Astralagus columbianus*	C	T
Dwarf evening-primrose	*Camissionia pygmaea*	NL	T
White eatonella	*Eatonella nivea*	NL	T
Hoover's desert-parsley	*Lomatium tuberosum*	C	T
Wanapum crazyweed	*Oxytropis campestris var. columbiana*	NL	T

Notes:
[1] NL = Not Listed; C = Candidate
[2] T = Threatened; E = Endangered

5.2.13.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Crab Creek site would involve the following environmental and institutional issues of concern:

- Crab Creek is critical habitat for anadromous fish species, including steelhead trout. The dam would be a barrier to anadromous fish passage and the reservoir would inundate anadromous and resident fish habitat in the creek.
- Approximately 18,663 acres of NWI wetlands would be impacted, requiring a Clean Water Act Section 404 permit and mitigation. The area is a breeding and migration resource for large numbers of waterfowl and shorebirds.
- Local roads would be inundated by the reservoir.
- An abandoned Chicago, Milwaukee, St. Paul and Pacific Railroad track would be inundated by the reservoir.
- Power transmission line facilities would be inundated by the reservoir.
- Agricultural land would be inundated by the reservoir.
- Farm structures would be inundated by the reservoir.
- Portions of the Columbia National Wildlife Refuge and the Lower Crab Creek State Wildlife Area would be inundated by the reservoir.
- Washington ground squirrel, a federal candidate species, has suitable habitat within the reservoir area.
- Northern leopard frog, a State of Washington-listed endangered species, has been observed in the reservoir area and suitable habitat would be inundated by the reservoir.
- Ferruginous hawk, a State of Washington threatened species, has been observed in the area and suitable habitat may inundated by the reservoir.

- Burrowing owl, loggerhead shrike, sage sparrow, sage thrasher, and black-tailed jack rabbit, all State of Washington candidate species, have been observed in the area and suitable habitat may be inundated by the reservoir.
- Northern wormwood, Columbia milkvetch, and Hoover's desert-parsley are federal candidate plant species that occur in the Crab Creek area. The State of Washington lists Northern wormwood as an endangered plant species. The State of Washington lists Dwarf evening-primrose, White eatonella, Wanapum crazyweed, Columbia milkvetch, and Hoover's desert-parsley as threatened species.

5.2.14 Alder Creek Dam and Reservoir Site

5.2.14.1 Site Location

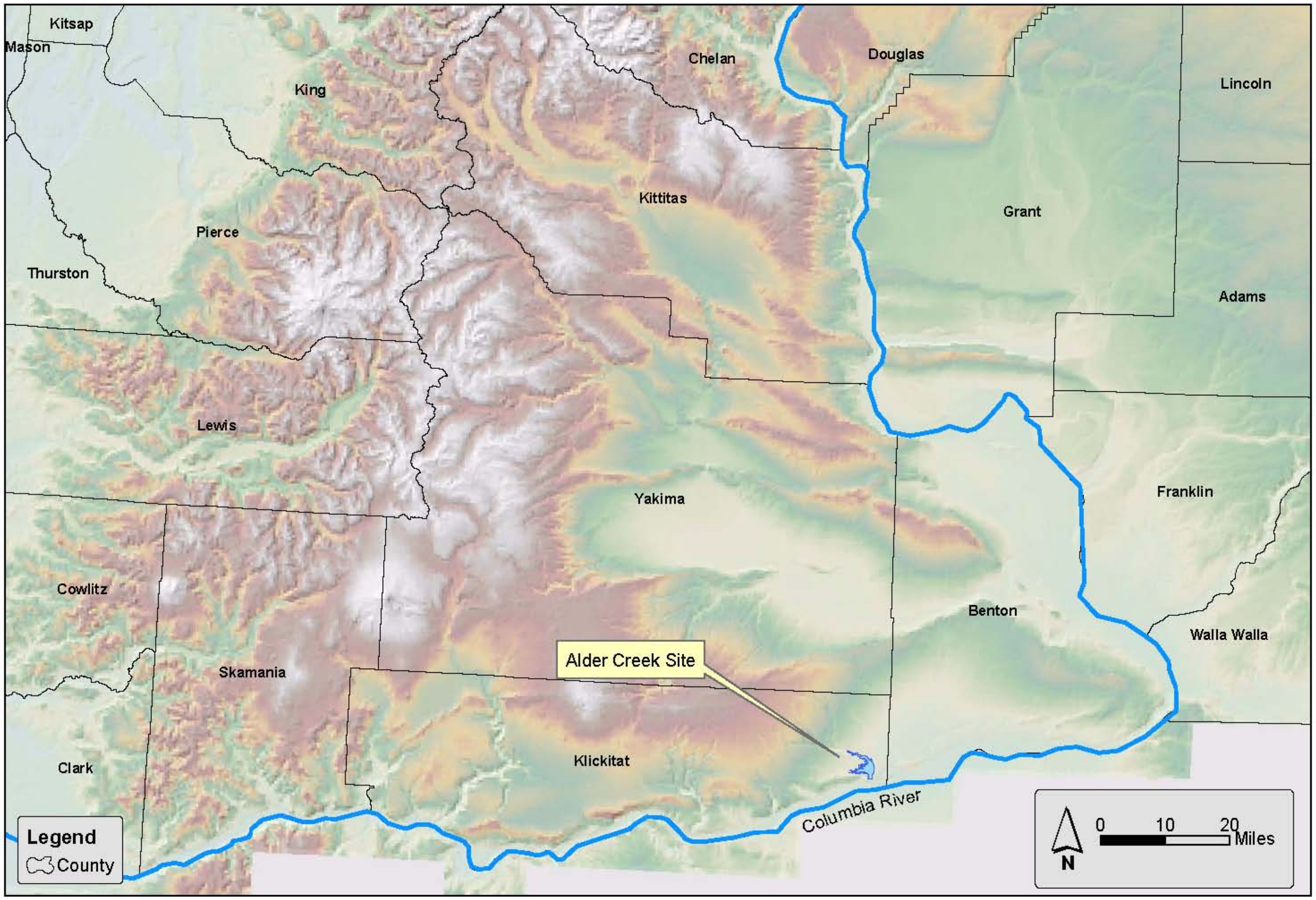
The Alder Creek site is located north of the Columbia River, approximately 33 river miles below McNary Dam. The dam and reservoir would be located in east Klickitat County in Townships 4 and 5 North, Range 23 East on the USGS 1:100,000 scale Hermiston, Oregon-Washington topographic quadrangle (see Site 15 on Map 1). Map 18 shows the potential Alder Creek Dam and Reservoir location in Klickitat County.

5.2.14.2 Previous Investigations

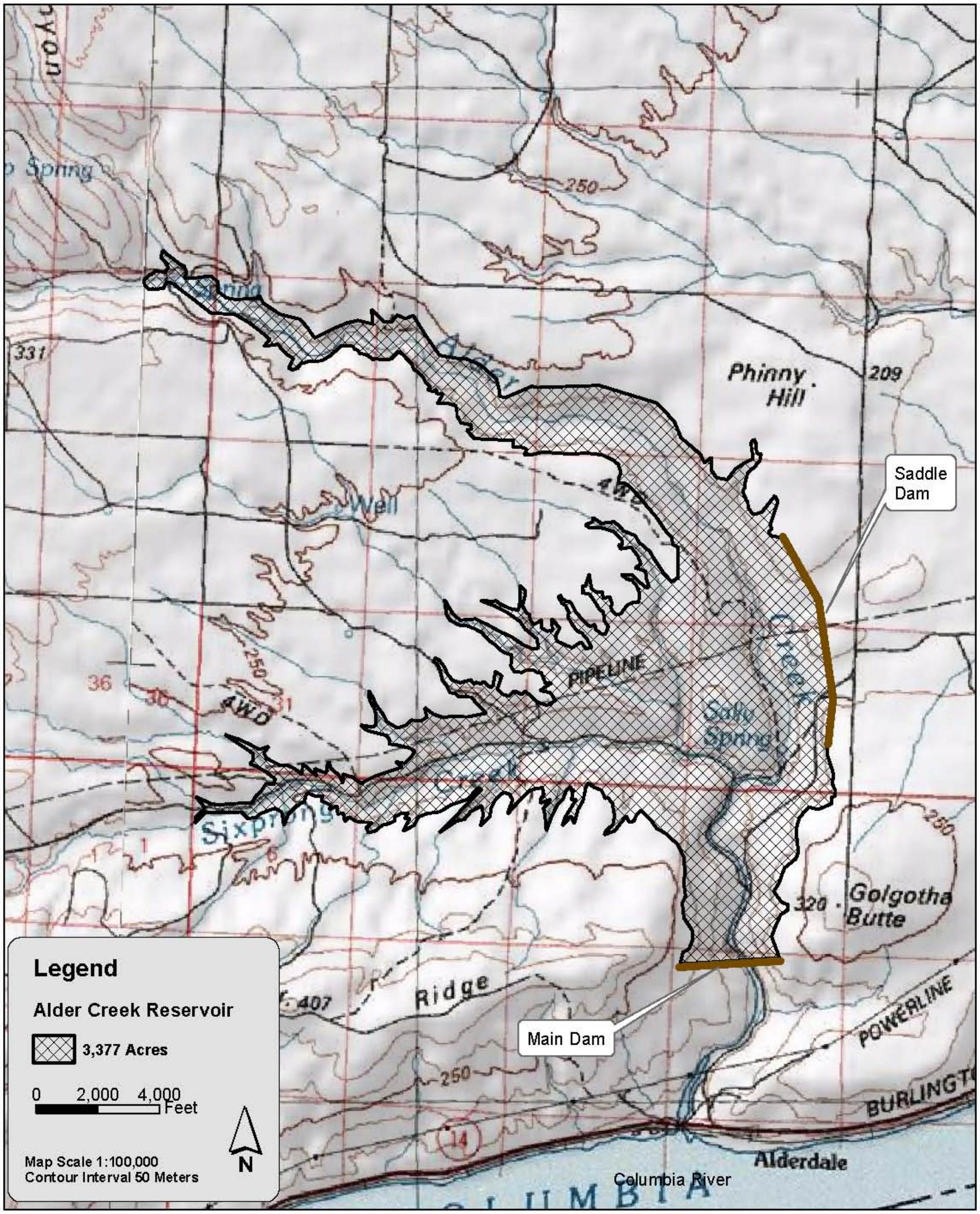
None identified.

5.2.14.3 Current Analysis

The Alder Creek dam and reservoir site would have a full-pool elevation at 700 feet MSL and would inundate portions of Alder and Sixprong Creeks (see Map 19). Figure 5-23 shows the elevation-capacity-area curve for the potential Alder Creek reservoir. Figure 5-24 shows a cross-section of the proposed dam site looking downstream.



Map 18
Alder Creek Dam and Reservoir Location Map



Map 19
Alder Creek Dam and Reservoir Site Map

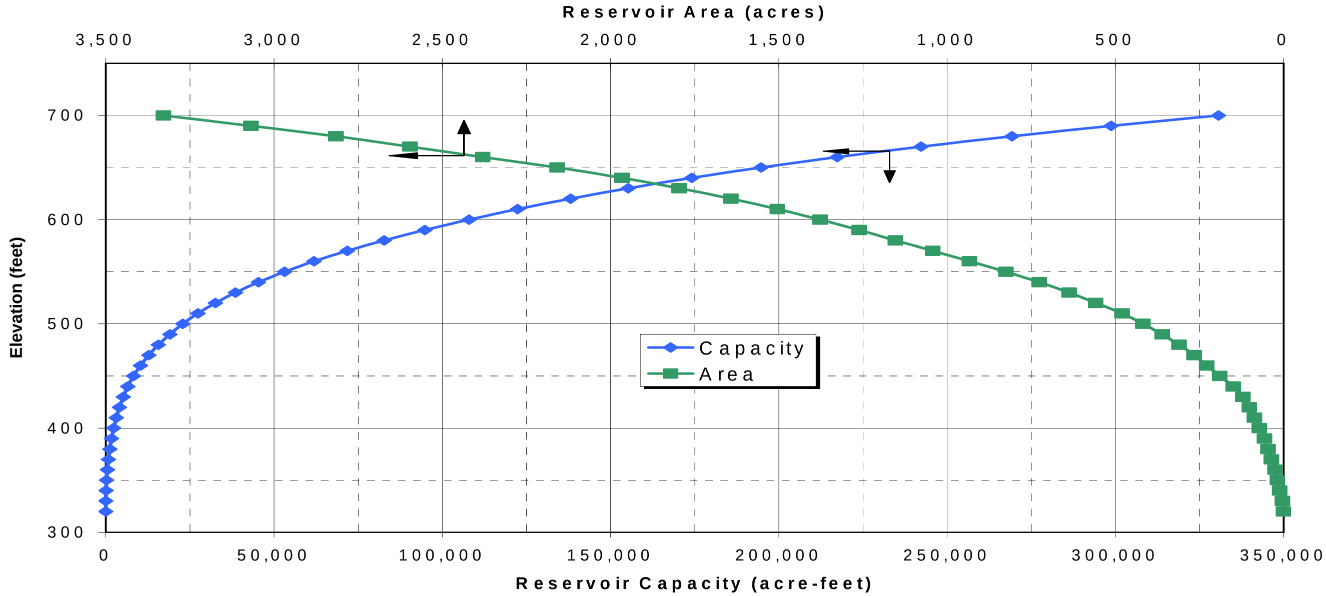


Figure 5-23. Alder Creek Reservoir Elevation-Capacity-Area Curves

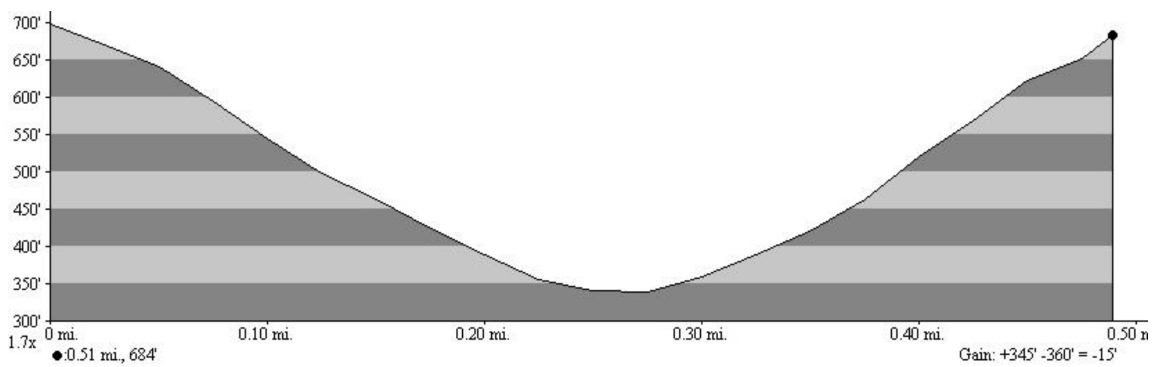


Figure 5-24. Alder Creek Dam Cross Section

Reservoir Volume

Total potential storage volume is estimated at approximately 330,000 acre-feet. Usable storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 300,000 acre-feet. To achieve maximum storage, it would be necessary to construct a saddle dam approximately 7,000 feet long and up to 70 feet maximum height along the eastern boundary of the potential reservoir.

Inundated Area

The inundated surface area at full-pool elevation would be approximately 3,400 acres.

Dam Size

The dam would be approximately 3,200 feet long by 335 feet high, including a 10-foot freeboard.

5.2.14.4 Water Sources and Availability

Drainage area at the Alder Creek Dam site would be nearly 200 square miles. Based on limited USGS streamflow gaging records on Alder Creek, the natural local inflow to the reservoir would average about 6,000 acre-feet per year. Columbia River water would be pumped to Alder Creek Reservoir from Lake Umatilla, which is impounded by John Day Dam. In comparison to the more than 20 million acre-feet of water availability from the Columbia River, the natural local inflows at the site would be insignificant.

The HYDROSIM model does not determine total Columbia River flow at John Day Dam, but the model does determine the total flow upstream at McNary Dam and downstream at Bonneville Dam. The drainage area at John Day Dam (226,000 square miles) is about midway between the drainage area at McNary Dam (214,000 square miles) and the drainage area at Bonneville Dam (239,900 square miles). Except for the months of September and October, the water availability at McNary Dam and Bonneville Dam can be determined as river flow in excess of the target flows specified at these dams in the 2000 BiOp. In September and October, the water availability at McNary and Bonneville dams was conservatively estimated as the same percentage of total flow availability as was available at Priest Rapids Dam. The water availability at John Day Dam was interpolated from the water availability at McNary Dam and Bonneville Dam based on difference in drainage areas at the dams. Water availability for Alder Creek Reservoir is presented in Table 5-30.

Table 5-30. Total Water Availability in Lake Umatilla (John Day Dam) (1000's of acre-feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	1,872	0	0	1,261	0	0	0	0	0	0	0	0	0	826	3,959
1930	2,327	0	0	0	337	0	0	0	0	0	0	0	0	1,055	3,719
1931	2,147	0	0	0	0	0	0	0	0	0	0	0	0	1,338	3,485
1932	2,184	0	0	0	0	2,071	0	1,375	3,163	789	550	26	0	1,155	11,314
1933	2,014	0	1,469	5,037	3,106	0	0	0	66	7,469	5,574	148	121	1,994	26,997
1934	3,750	2,503	8,907	12,520	7,013	4,532	1,183	1,409	1,278	0	0	0	0	987	44,082
1935	2,036	0	908	4,413	4,493	0	0	0	0	0	364	140	0	1,198	13,552
1936	2,185	0	0	0	0	116	0	0	4,478	0	0	0	0	639	7,417
1937	2,185	0	0	0	0	0	0	0	0	0	0	0	0	739	2,924
1938	2,409	0	768	5,672	848	3,293	0	57	4,378	474	156	0	0	1,224	19,279
1939	2,120	0	0	1,843	0	325	0	0	0	0	0	0	0	729	5,017
1940	2,376	0	310	978	159	3,326	0	0	0	0	0	0	0	554	7,704
1941	2,081	0	974	2,015	0	0	0	0	0	0	0	0	0	965	6,035
1942	1,945	0	3,449	5,496	235	0	0	0	0	616	754	121	0	877	13,493
1943	2,183	0	1,298	4,767	3,397	3,841	2,080	2,434	4,185	2,049	2,470	146	0	774	29,624
1944	2,014	0	86	1,695	0	0	0	0	0	0	0	0	0	974	4,770
1945	1,938	0	0	0	0	0	0	0	0	0	0	0	0	451	2,389
1946	2,255	0	217	2,944	1,997	4,006	0	436	5,177	467	1,192	126	0	1,320	20,137
1947	1,611	0	4,826	5,470	3,862	4,146	0	0	2,911	76	512	102	0	1,047	24,563
1948	5,106	1,627	2,762	5,768	1,112	1,926	0	211	6,890	20,848	3,000	117	101	2,608	52,076
1949	2,515	0	911	2,242	1,401	6,154	0	1,151	5,725	453	0	0	0	296	20,849
1950	2,052	0	148	2,982	4,639	7,084	253	673	2,461	9,011	4,158	141	0	1,651	35,253
1951	3,196	2,483	6,052	8,660	8,149	4,892	89	1,457	7,098	41	1,941	168	0	1,978	46,204
1952	4,246	391	3,185	4,864	2,951	2,831	598	2,098	7,437	306	0	0	0	745	29,652
1953	1,930	0	0	2,676	4,350	177	0	0	1,086	5,316	2,353	95	0	1,256	19,239
1954	2,397	77	2,232	3,925	4,410	2,387	0	19	3,629	6,690	4,228	1,119	115	5,512	36,740
1955	3,233	1,127	1,982	1,002	0	0	0	0	0	7,635	6,722	182	2	1,407	23,291
1956	3,075	1,857	5,984	9,484	3,036	6,333	366	3,822	11,389	9,928	3,069	160	0	1,274	59,777
1957	2,471	0	2,568	3,422	0	2,367	549	68	7,727	6,609	0	0	0	744	26,524
1958	1,970	0	372	2,964	3,492	2,700	0	461	5,216	2,686	0	0	0	920	20,782
1959	1,945	966	3,576	8,420	4,674	2,473	0	0	1,783	5,186	3,589	128	0	4,982	37,722
1960	6,503	2,996	4,651	4,375	1,224	2,028	1,239	562	42	841	641	78	0	1,147	26,327
1961	2,211	516	914	3,785	4,374	3,688	0	0	657	8,722	0	0	0	546	25,412
1962	1,937	0	55	3,562	0	0	69	1,009	20	0	270	0	0	744	7,667
1963	2,355	994	3,519	3,769	2,281	1,276	0	0	93	0	207	78	0	1,396	15,968
1964	1,710	0	359	3,441	606	0	0	0	0	8,509	5,353	85	0	2,240	22,304
1965	3,592	153	6,673	10,301	7,448	4,967	0	1,737	5,110	3,784	539	112	0	1,035	45,452
1966	2,304	216	1,930	4,570	0	141	0	0	0	0	826	121	0	805	10,913
1967	1,847	0	1,109	5,523	5,520	622	0	0	0	7,322	3,820	43	0	1,609	27,417
1968	2,275	213	1,962	4,754	3,806	2,426	0	0	0	934	2,723	58	0	3,063	22,213
1969	3,445	1,454	2,780	7,728	4,522	2,971	1,172	1,536	4,340	856	248	0	0	851	31,902
1970	2,020	0	509	4,929	3,317	459	0	0	0	3,368	0	0	0	0	14,603
1971	1,723	0	429	7,058	8,786	3,932	0	689	11,185	7,984	3,408	0	0	1,161	46,355
1972	1,686	97	1,922	6,345	7,458	13,139	1,792	0	9,205	12,436	4,968	569	118	1,975	61,710
1973	2,175	0	2,435	5,347	0	0	0	0	0	0	0	0	0	0	9,958
1974	1,786	0	4,412	13,116	8,792	6,383	1,057	2,798	8,622	13,032	7,825	234	99	2,039	70,195
1975	1,624	0	760	4,742	2,278	3,709	0	0	2,529	5,782	5,353	0	0	1,195	27,973
1976	2,742	2,058	8,085	8,393	4,693	3,182	855	580	7,529	121	3,959	1,482	1,100	6,353	51,133
1977	2,415	0	301	1,875	0	0	0	0	0	0	0	0	0	593	5,184
1978	1,328	0	1,992	3,547	1,201	4,558	0	0	1,917	0	1,382	0	0	1,278	17,202
Average	2,429	395	1,956	4,354	2,599	2,369	226	492	2,747	3,207	1,643	116	33	1,405	23,969
Maximum	6,503	2,996	8,907	13,116	8,792	13,139	2,080	3,822	11,389	20,848	7,825	1,482	1,100	6,353	70,195
Minimum	1,328	0	0	0	0	0	0	0	0	0	0	0	0	0	2,389
Count	50	17	41	44	35	35	13	21	31	32	31	25	7	48	50

5.2.14.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Alder Creek Dam and Reservoir is shown in Table 5-31.

Table 5-31. Pre-Appraisal-Level Cost Estimate for Alder Creek Dam and Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	$ 123,000,000	
2. Spillway/Outlet Works	$ 15,000,000	
3. Pumping Plant, Pumps & Motors	$ 123,000,000	
4. Waterway (tunnel)	$ 10,000,000	
Sub-Total (Field Costs)	$ 271,000,000	
Allowances		
Mobilization (5% x Field Costs)	$ 13,550,000	
Sub-Total (Field Costs plus Mobilizaton)	$ 284,550,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	$ 42,682,500	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	$ 327,232,500	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	$ 81,808,125	
Direct Construction Costs	$ 409,040,625	
Indirect Costs (20% to 35% of Direct Construction Costs)	$ 81,808,125	$ 143,164,219
Range Totals	**$ 490,848,750**	**$ 552,204,844**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.14.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Alder Creek Reservoir could be used to supplement Columbia River instream flows for anadromous fish and could be released during April through August when 2000 BiOp target flows are not met in the Columbia River downstream of McNary Dam. The Alder Creek Reservoir would store enough water to meet a range of 3 to 10 percent of the 2000 BiOp target flows below McNary Dam during a one-month period from April through August based on monthly average flows at Grand Coulee, Priest Rapids and Bonneville dams.

Agricultural Irrigation

An arbitrary distance of 50 miles for conveyance of stored water was used to estimate potential agricultural use. Beyond this distance, conveyance costs would make agricultural use uneconomical. Parts of Klickitat (20,239 irrigated acres – IA), Yakima (77,389 IA) and Benton (153,254 IA) Counties lie within the 50-mile range for irrigation water. The Alder Creek site could be a moderate potential resource for agricultural irrigation in a three-county area.

M&I Water Supply

There could be future potential benefits from using Alder Creek storage water for an M&I water supply. The population center of note within a 50-mile radius of the site would be the Pasco/Kennewick/Richland metro area; local water supplies are expected to be sufficient to continue meeting future M&I water supply needs for the near term. The Alder Creek Reservoir could be a long-term resource to support expected population growth in the future.

Recreation

There would be some opportunities for recreational boating on the potential Alder Creek reservoir. Development of a fishing resource would require fish stocking and fisheries management in the potential reservoir.

5.2.14.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.14.8 Regional and Local Geology

The Alder Creek site is in the southwest part of the Columbia River Plateau, a structural and topographic basin, which encompasses most of the Columbia River drainage. Exposed bedrock at this site are basalts of the upper Miocene Saddle Mountain Basalt unit of the Columbia River Basalt Group. The Saddle Mountains Basalt contains frequent sedimentary interbeds that may be from a few inches to several feet thick. The Saddle Mountains Basalt is approximately 500 feet thick at this location. Exposed rock outcrops are not extensively weathered. Sediments are estimated to be 50 to 100 feet thick at this location in the canyon floor (Drost and Whiteman, 1986; Swanson et al., 1979). This site is located within a group of long anticlinal/synclinal features that may be associated with the Yakima Fold Belt. The axis of the folds are parallel to the Columbia River and therefore cross the site approximately perpendicular to the canyon. A series of east-west trending thrust faults begins about 10 miles west of the site and extends to The Dalles area (Drost and Whiteman, 1986).

5.2.14.9 Potential Environmental and Institutional Issues

There would be no direct long-term impacts on anadromous fish populations from construction and operation of a dam and reservoir at this site; it is not included in the Northwest StreamNet anadromous species stream resource database. Alder Creek is located in Water Resource Inventory Area (WRIA) #31; there is no data on Alder Creek on the WRIA #31 website (WRIA 31, 2005). Alder Creek is not listed for water quality violations in the 2003 Washington State surface water quality report (Ecology, 2004).

There are no major structures in the Alder Creek or Sixprong Creek drainages. Alderdale Road is located in the lower Alder Creek canyon and would need to be relocated, but there are no major traffic routes through the area of potential inundation. A petroleum pipeline crosses the upper part of the potential reservoir and would need to be relocated. The area around the potential reservoir site is extensively cropped, but there is no significant agricultural development in the reservoir area proper. There are no wildlife refuges designated in the potential reservoir area. The reservoir would inundate approximately 18 acres of NWI wetlands at full pool elevation.

The Washington State GAP Analysis database (WAGAP, 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with predicted habitat or recorded occurrences in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. Habitat in the Alder Creek site is arid steppe and grasslands surrounding a small riparian core in the southern reservoir area; there is considerable irrigated agriculture to the east and a small amount of irrigated agriculture on the west. North of the reservoir site is dryland agriculture. Table 5-32 summarizes listed vertebrate species that have potential habitat in the area of the potential Alder Creek dam and reservoir site.

Table 5-32. Listed Vertebrate Species With GAP Habitat in the Alder Creek Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Sagebrush lizard	*Sceloporus graciosus*	NL	SC
Striped whipsnake	*Masticophis taeniatus*	NL	SC
Western toad	*Bufo boreas*	NL	SC
Burrowing owl	*Athene cunicularia*	NL	SC
Golden eagle	*Aquila chryseatos*	NL	SC
Lewis' woodpecker	*Melanerpes lewis*	NL	SC
Loggerhead shrike	*Lanius ludovicianus*	NL	SC
Pileated woodpecker	*Dryocopus pileatus*	NL	SC
Vaux's swift	*Chaetura vauxi*	NL	SC
Black-tailed jack rabbit	*Lepus californicus*	NL	SC
Townsend's big-eared bat	*Coryhorhinus townsendii*	NL	SC
Townsend's ground squirrel	*Spermophilus townsendii*	C	SC
Western gray squirrel	*Sciuris griseus*	NL	ST
White-tailed jack rabbit	*Lepus townsendii*	NL	SC

Notes:
[1] NL = Not Listed; C = Candidate
[2] SC = State Candidate; ST = State Threatened

Small animals with limited dispersal capacity and home ranges impacted by dam construction or inundated by the reservoir would be at greatest risk. Large mobile species and birds could disperse from the construction and inundation zones. Bats would generally not be impacted unless a dam or reservoir would cover or inundate a hibernaculum. The herp species have potential habitat in the area of the reservoir, but no observations. There are observations of breeding occurrences for burrowing owl (confirmed) and loggerhead shrike (possible); the other bird species have potential habitat present without observations. Black-tailed and white-tailed jack rabbits have been observed just west of the site and have potential habitat in the reservoir area. Western gray squirrel has marginal habitat in the upper reservoir area.

5.2.14.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Alder Creek site would involve the following environmental and institutional issues of concern:

- Approximately 18 acres of NWI wetlands would be impacted, requiring a Clean Water Act Section 404 permit and mitigation.
- Alderdale Road would be inundated by the reservoir.
- A petroleum pipeline would be inundated by the reservoir.
- Townsend's ground squirrel, a federal candidate species, has suitable habitat within the reservoir area.
- Western gray squirrel, a State of Washington threatened species, has been observed in the area and suitable habitat may inundated by the reservoir.
- Burrowing owl, loggerhead shrike, black-tailed jack rabbit, and white-tailed jack rabbit, all State of Washington candidate species, have been observed in the area and suitable habitat may be inundated by the reservoir.

5.2.15 Rock Creek East Dam and Reservoir Site

5.2.15.1 Site Location

The Rock Creek East site is located north of the Columbia River approximately 13 river miles upstream from John Day Dam. The dam and reservoir would be located in eastern Klickitat County in Township 3 North, Ranges 18 and 19 East on the USGS 1:100,000 scale The Dalles, Oregon-Washington topographic quadrangle (see Site 16 on Map 1). Map 20 shows the potential Rock Creek East Dam and Reservoir location in Klickitat County.

5.2.15.2 Previous Investigations

None identified.

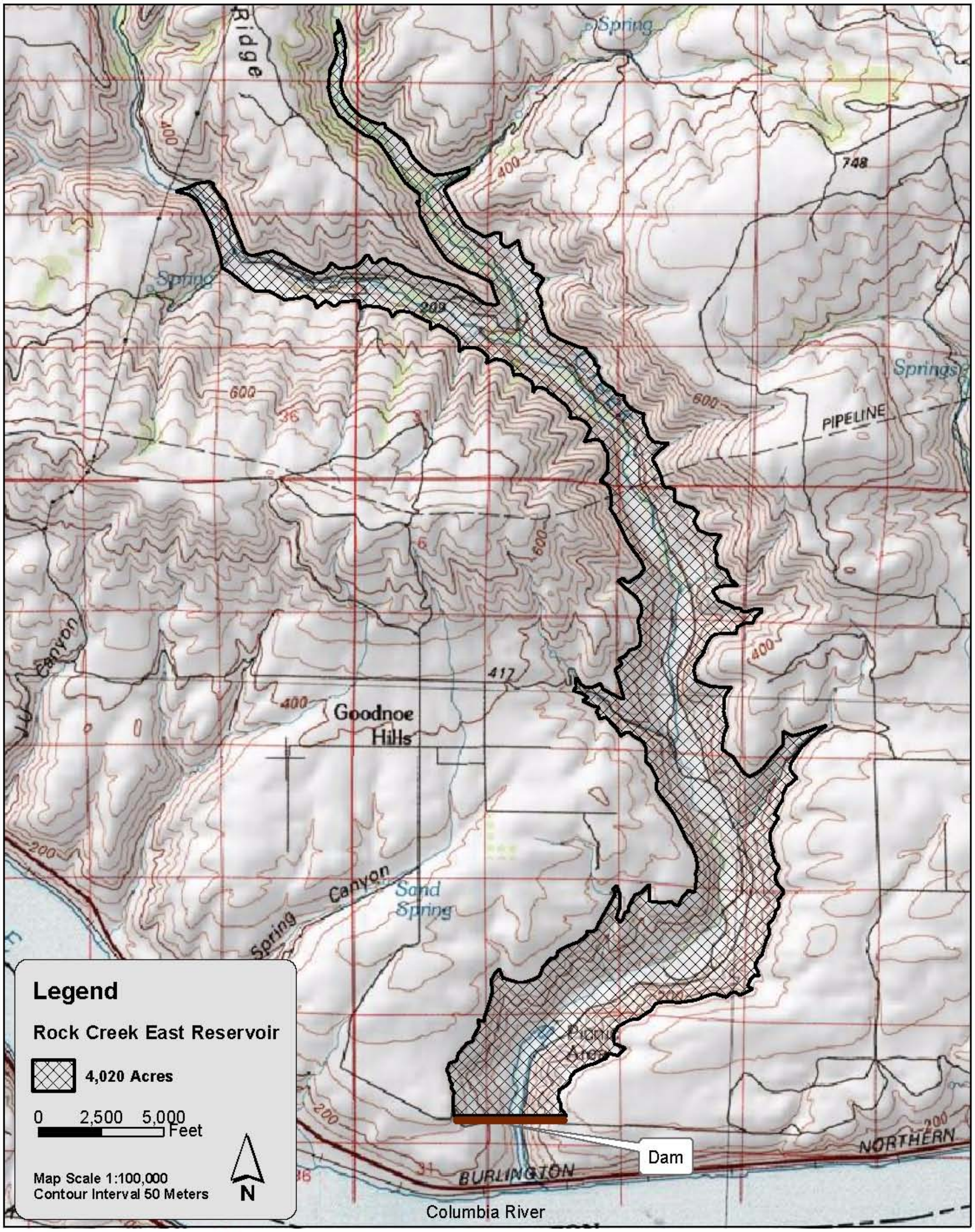
5.2.15.3 Current Analysis

The Rock Creek East dam and reservoir site would have a full-pool elevation at 900 feet MSL and would inundate portions of Squaw Creek and Rock Creek (see Map 21). Figure 5-25 shows the elevation-capacity-area curve for the potential Rock Creek East reservoir. Figure 5-26 shows a cross-section of the proposed dam site looking downstream.

Reservoir Volume

Total potential storage volume is estimated at approximately 1,000,000 acre-feet. Usable storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 900,000 acre-feet.

Map 20
Rock Creek East Dam and Reservoir Location Map



Map 21
Rock Creek East Dam and Reservoir Site Map

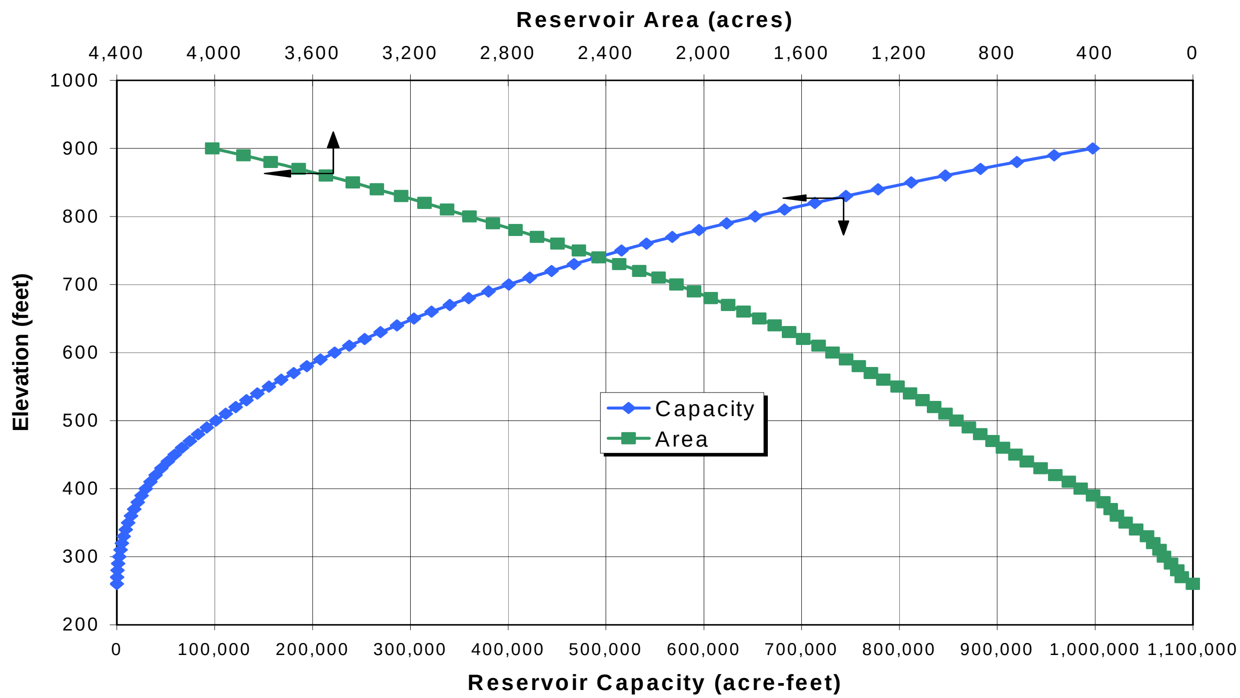


Figure 5-25. Rock Creek East Reservoir Elevation-Capacity-Area Curves

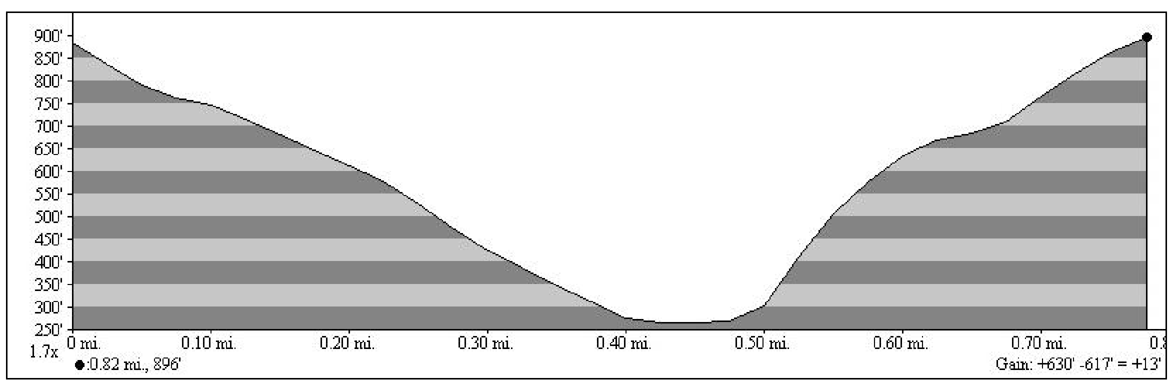


Figure 5-26. Rock Creek East Dam Cross Section

Inundated Area

The inundated surface area at full-pool elevation would be approximately 4,000 acres.

Dam Size

The dam would be approximately 4,500 feet long by 640 feet high, including a 10-foot freeboard.

5.2.15.4 Water Sources and Availability

Drainage area at the Rock Creek East Dam site would be approximately 220 square miles. Based on limited USGS streamflow gaging records on Alder Creek, the natural local inflow to the reservoir would average roughly about 30,000 acre-feet per year. In comparison to the nearly 24 million acre-feet of water availability from the Columbia River, the natural local inflows at the site would be insignificant. The diversion point for the Rock Creek East Dam and Reservoir site would be in Umatilla Lake, which is impounded by John Day Dam. Water availability for Umatilla Lake would be the same as previously presented in section 5.2.15.4 for the Alder Creek Dam and Reservoir site.

5.2.15.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Rock Creek East Dam and Reservoir is shown in Table 5-33.

Table 5-33. Pre-Appraisal-Level Cost Estimate for Rock Creek East Dam and Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	$ 417,000,000	
2. Spillway/Outlet Works	$ 40,000,000	
3. Pumping Plant, Pumps & Motors	$ 188,000,000	
4. Waterway (tunnel)	$ 15,000,000	
Sub-Total (Field Costs)	$ 660,000,000	
Allowances		
Mobilization (5% x Field Costs)	$ 33,000,000	
Sub-Total (Field Costs plus Mobilizaton)	$ 693,000,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	$ 103,950,000	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	$ 796,950,000	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	$ 199,237,500	
Direct Construction Costs	$ 996,187,500	
Indirect Costs (20% to 35% of Direct Construction Costs)	$ 199,237,500	$ 348,665,625
Range Totals	**$ 1,195,425,000**	**$ 1,344,853,125**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.15.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Rock Creek East Reservoir could be used to supplement Columbia River instream flows for anadromous fish and could be released during April through August when 2000 BiOp target flows are not met in the Columbia River downstream of McNary Dam. The Rock Creek East Reservoir would store enough water to meet a range of 10 to 30 percent of the 2000 BiOp target flows below McNary Dam during a one-month period from April through August based on monthly average flows at Grand Coulee, Priest Rapids and Bonneville dams.

Agricultural Irrigation

An arbitrary distance of 50 miles for conveyance of stored water was used to estimate potential agricultural use. Beyond this distance, conveyance costs would make agricultural use uneconomical. Parts of Klickitat (20,239 irrigated acres – IA), Yakima (77,389 IA) and Benton (153,254 IA) Counties lie within the 50-mile range for irrigation water. The Rock Creek East site could be a limited potential resource for agricultural irrigation in a three-county area.

M&I Water Supply

There would be minimal potential benefits from using Rock Creek East storage water for an M&I water supply. The only population centers of note within a 50-mile radius of the site would be the Cities of Sunnyside (pop. 14,000) and Grandview (pop. 8,400), but local water supplies are expected to be sufficient to continue meeting future M&I water supply needs.

Recreation

There would be some opportunities for recreational boating on the potential Rock Creek East reservoir. Development of a fishing resource would require fish stocking and fisheries management in the potential reservoir.

5.2.15.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.15.8 Regional and Local Geology

The Rock Creek East site is located north of the Columbia River in the southwest part of the Columbia Plateau, a structural and topographic basin, which encompasses most of the Columbia River drainage. Exposed rock at this site is the middle to upper Miocene Wanapum Basalt, which is probably about 200 feet thick in this vicinity and may consist of multiple individual flows. Contacts between individual flows in the Wanapum Basalt are sometimes rubbly and fractured, and these contact zones tend to be zones of higher permeability (Drost and Whiteman, 1986). Exposed rock outcrops are generally unweathered. Overlying the Wanapum Basalt at higher elevations is a sedimentary unit informally designated the Mabton Member of the Ellensburg Formation, of varying thickness. This sedimentary layer is interbed between the Wanapum Basalt and the younger Saddle Mountains Basalt, exposed in outcrops east of the site. The Mabton Member typically consists of silt or clay but sometimes includes sand and gravel. Overburden at the site consists of Quaternary alluvial deposits of unknown thickness, although sediments in this area are typically between 50 and 200 feet thick (Swanson et al., 1979). This site is located within a group of long anticlinal/synclinal features that may be associated with the Yakima Fold Belt. The axis of the folds are parallel to the Columbia River and therefore cross the site approximately perpendicular to the canyon. A series of east-west trending thrust faults associated with the fold belt crosses Rock Creek near the site, along the axis of a syncline feature (Drost and Whiteman, 1986).

5.2.15.9 Potential Environmental and Institutional Issues

Rock Creek East is located in Water Resource Inventory Area (WRIA) # 31. Rock Creek East is not listed as a Section 303 (d) stream (WRIA 31 website 2005) and was not listed for surface water quality violations in the 2003 water quality report (Ecology, 2004). There would be direct long-term impacts on anadromous fish populations from construction and operation of a dam and reservoir at this site. Rock Creek and its major tributary, Squaw Creek, are used by chinook salmon and steelhead trout and the Rock Creek East dam would be a fish passage barrier unless a fish ladder were constructed.

The potential Rock Creek East dam and reservoir would inundate an existing boat ramp, picnic area and access road (Walker Grade).

There are no major structures or traffic routes in the Squaw Creek or Rock Creek drainages. A petroleum pipeline crosses the upper part of the potential reservoir and would need to be relocated. The area around the potential reservoir site is extensively cropped, but there is no significant agricultural development in the potential reservoir area proper. There are no wildlife refuges designated in the potential reservoir area. Approximately 32 acres of NWI wetlands would be inundated at full-pool elevation.

The Washington State GAP Analysis database (WAGAP, 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with predicted habitat or recorded occurrences in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. Habitat in the Rock Creek East reservoir site is grassy steep canyon walls and dry steppe with small patches of conifer forest bordering the north end and dryland agriculture bordering the south end. Table 5-34 summarizes listed vertebrate species that have potential habitat in the area of the potential Rock Creek East dam and reservoir site.

Table 5-34. Listed Vertebrate Species With GAP Habitat in the Rock Creek East Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Sagebrush lizard	*Sceloporus graciosus*	NL	SC
Western toad	*Bufo boreas*	NL	SC
Burrowing owl	*Athene cunicularia*	NL	SC
Golden eagle	*Aquila chryseatos*	NL	SC
Lewis' woodpecker	*Melanerpes lewis*	NL	SC
Loggerhead shrike	*Lanius ludovicianus*	NL	SC
Pileated woodpecker	*Dryocopus pileatus*	NL	SC
Black-tailed jack rabbit	*Lepus californicus*	NL	SC
Townsend's big-eared bat	*Coryhorhinus townsendii*	NL	SC
Western gray squirrel	*Sciuris griseus*	NL	ST
White-tailed jack rabbit	*Lepus townsendii*	NL	SC

Notes:
[1] NL = Not Listed
[2] SC = State Candidate; ST = State Threatened

Small animals with limited dispersal capacity and home ranges impacted by dam construction or inundated by the reservoir would be at greatest risk. Large mobile species and birds could disperse from the construction and inundation zones. Bats would generally not be impacted unless a dam or reservoir would cover or inundate a hibernaculum. Sagebrush lizard habitat would be inundated by the reservoir. Western toad has marginal habitat in the area of the potential reservoir, but an occurrence is recorded at what would be the upper area of the reservoir. Golden eagle and Lewis' woodpecker have probably nested in the area. Black-tailed and white-tailed jack rabbits and western gray squirrels have habitat in the area, but none have specific occurrences recorded.

5.2.15.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Rock Creek East site would involve the following environmental and institutional issues of concern:

- Rock Creek and its major tributary, Squaw Creek, are habitat for federally-listed anadromous fish species, including chinook salmon and steelhead trout. The dam would be a barrier to anadromous fish passage and the reservoir would inundate anadromous and resident fish habitat in the creek.
- Approximately 32 acres of NWI wetlands would be impacted, requiring a Clean Water Act Section 404 permit and mitigation.
- The Walker Grade access road, boat ramp, and picnic area would be inundated by the reservoir.
- A petroleum pipeline would be inundated by the reservoir.
- Western gray squirrel, a State of Washington threatened species, has been observed in the area and suitable habitat may inundated by the reservoir.

- Golden eagle, Lewis' woodpecker, and Western toad, all State of Washington candidate species, have been observed in the area and suitable habitat may be inundated by the reservoir.

5.2.16 Rattlesnake Creek Dam and Reservoir Site

The Rattlesnake Creek Dam and Reservoir site is located north of the Columbia River in Klickitat County (see Site 17 on Map 1). The Rattlesnake Creek site exceeded the 800-foot maximum pumping lift assumption and was not evaluated in detail.

5.2.17 Little White Salmon Dam and Reservoir Site

The Little White Salmon Dam and Reservoir site is located north of the Columbia River in Skamania County (see Site 18 on Map 1). The Little White Salmon site exceeded the 800-foot maximum pumping lift assumption and was not evaluated in detail.

5.2.18 Panther Creek Dam and Reservoir Site

The Panther Creek Dam and Reservoir site is located north of the Columbia River in Skamania County (see Site 19 on Map 1). The Panther Creek site did not meet the 300,000 acre-feet minimum active storage assumption and was not evaluated in detail.

5.2.19 Rock Creek West Dam and Reservoir Site

The Rock Creek West Dam and Reservoir site is located north of the Columbia River in Skamania County (see Site 20 on Map 1). The Rock Creek West site exceeded the maximum pumping lift assumption of 800 feet from the Columbia River; at the acceptable full-pool elevation the potential reservoir did not meet the minimum acceptable active storage assumption of 300,000 acre-feet. Therefore, the site was not evaluated in detail.

5.2.20 Kalama River Dam and Reservoir Site

5.2.20.1 Site Location

The Kalama River site is located north of the City of Kalama, approximately 13.3 miles upstream from the confluence with the Columbia River. The proposed dam site is located at river mile 13.3, approximately 2.6 river miles upstream from the Lower Kalama River Falls and 2.4 miles upstream from the Kalama Falls Salmon Hatchery. The straight line distance to the Columbia River is approximately 5.4 miles. The reservoir would extend upstream to approximately river mile 28. The dam and reservoir would be located in Cowlitz County in Townships 6 and 7 North, Ranges 1 and 2 East on the USGS 1:100,000 scale Mount St. Helens and Vicinity, Washington-Oregon topographic quadrangle (see Site 21 on Map 1). Map 22 shows the potential Kalama River Dam and Reservoir location in Klickitat County.

5.2.20.2 Previous Investigations

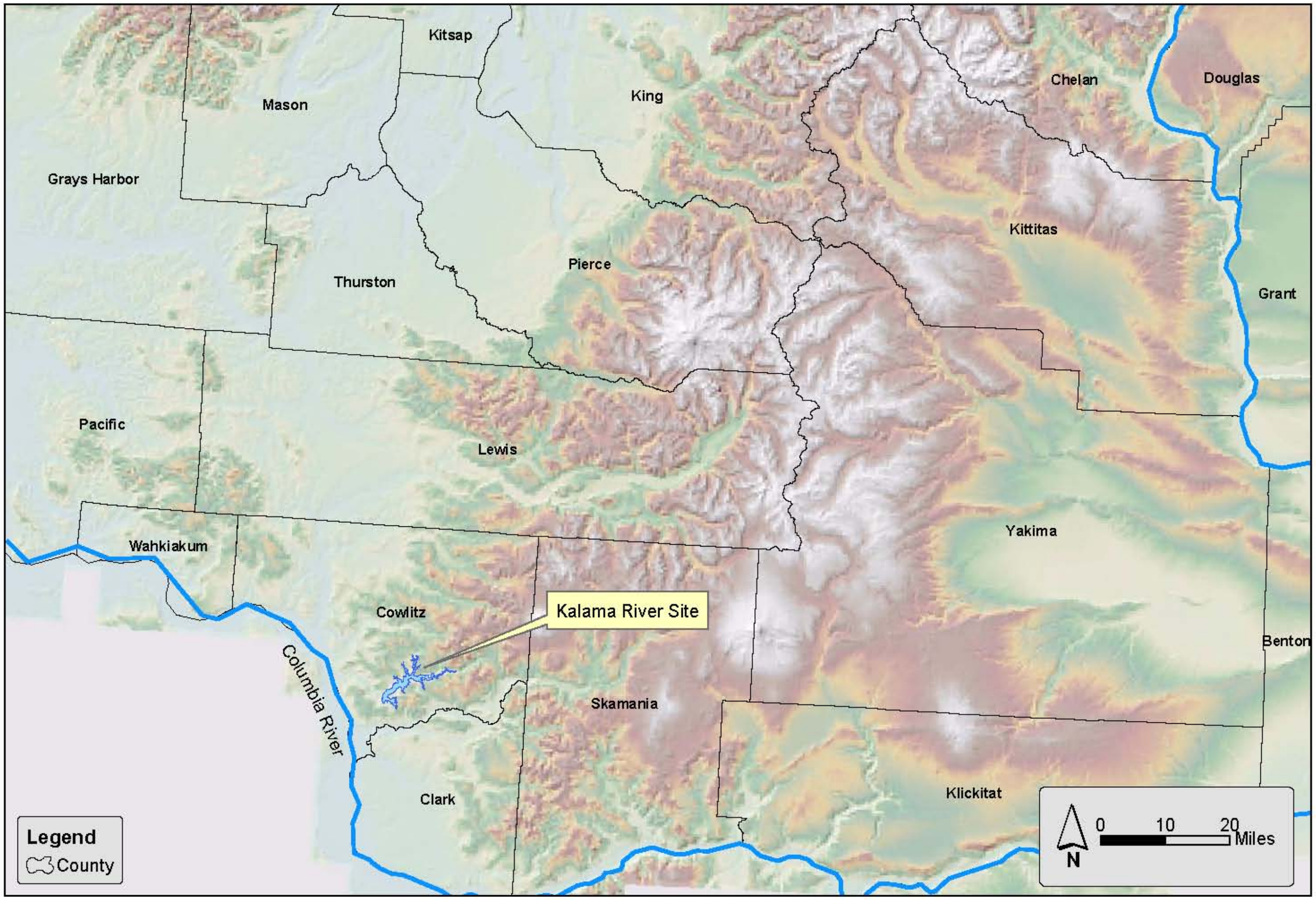
None identified.

5.2.20.3 Current Analysis

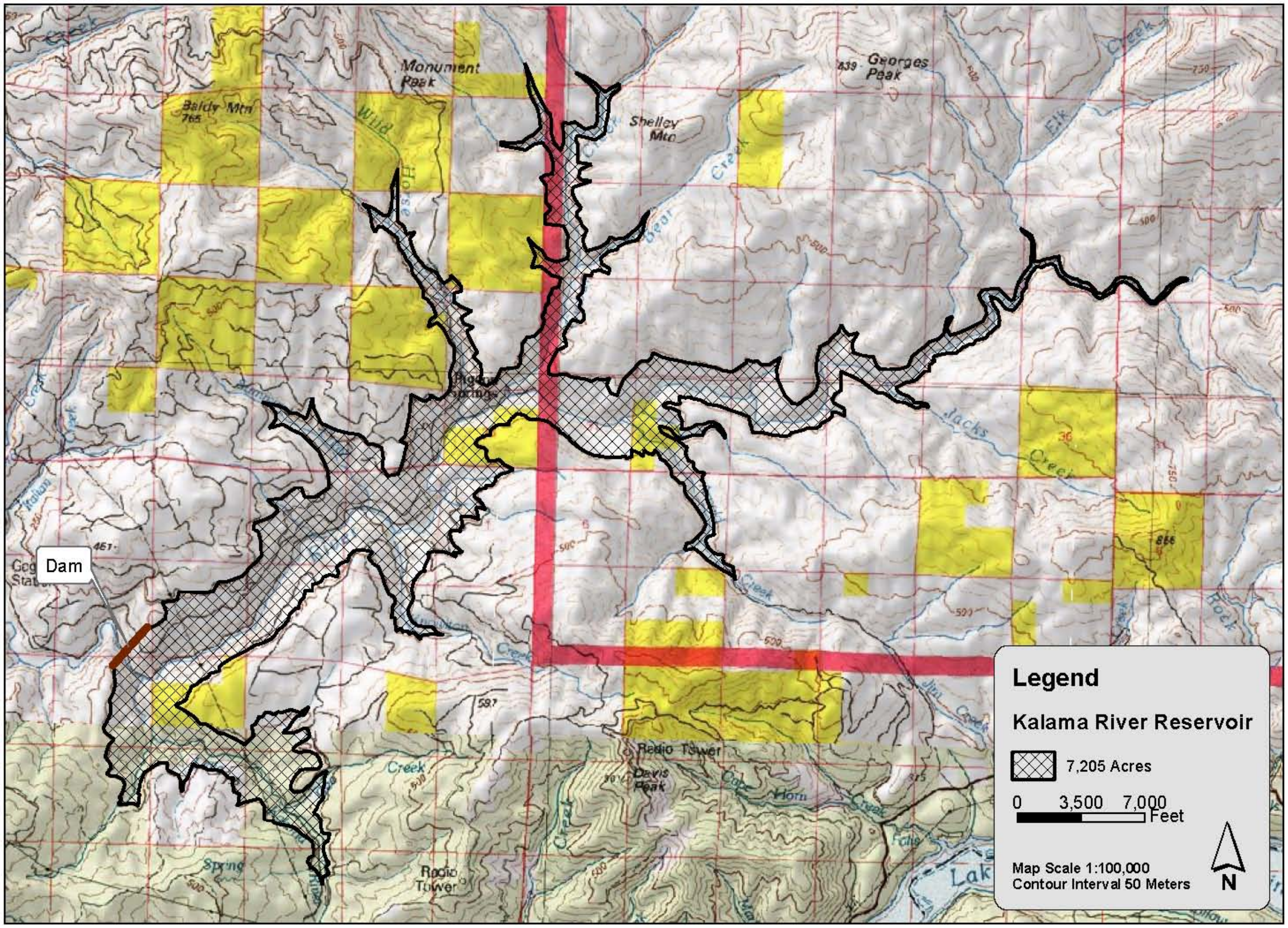
The Kalama River dam and reservoir site would have a full-pool elevation at 800 feet MSL and would inundate portions of the middle Kalama River valley (see Map 23). Figure 5-27 shows the elevation-capacity-area curve for the potential Kalama River reservoir. Figure 5-28 shows a cross-section of the proposed dam site looking downstream.

Reservoir Volume

Total potential storage volume is estimated at approximately 1,185,000 acre-feet. Usable storage volume, assuming a 10 percent reduction of total volume for inactive and dead storage, would be approximately 1,070,000 acre-feet.



Map 22
Kalama River Dam and Reservoir Location Map



Map 23
Kalama River Dam and Reservoir Site Map

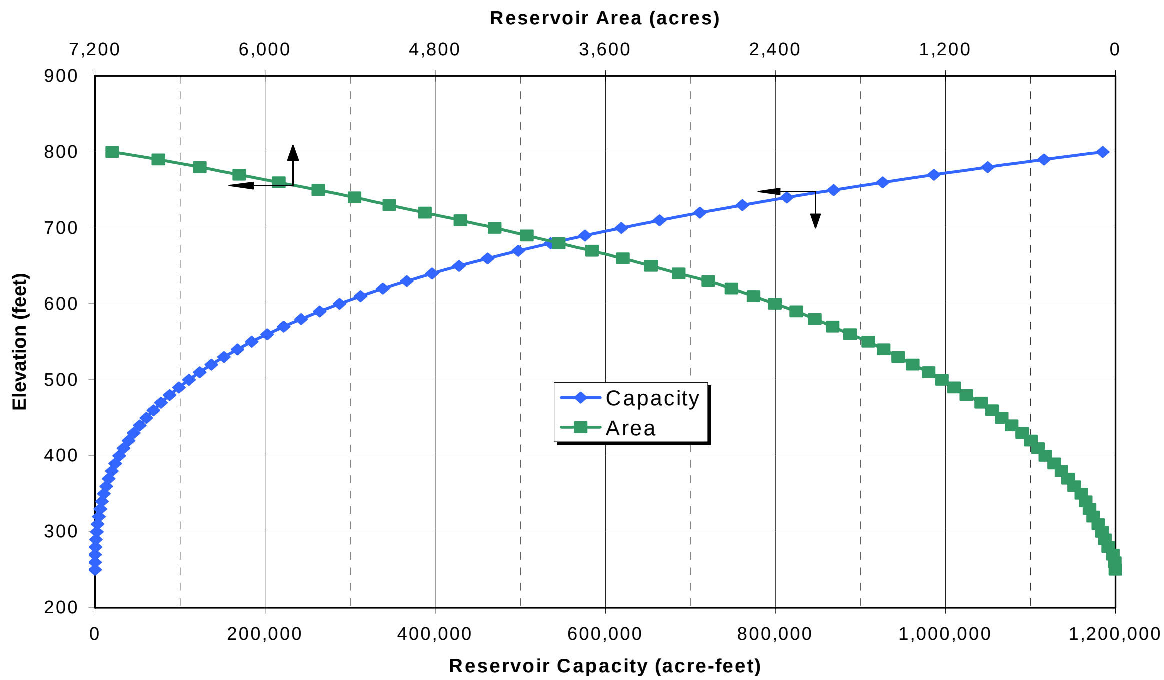


Figure 5-27. Kalama River Reservoir Elevation-Capacity-Area Curves

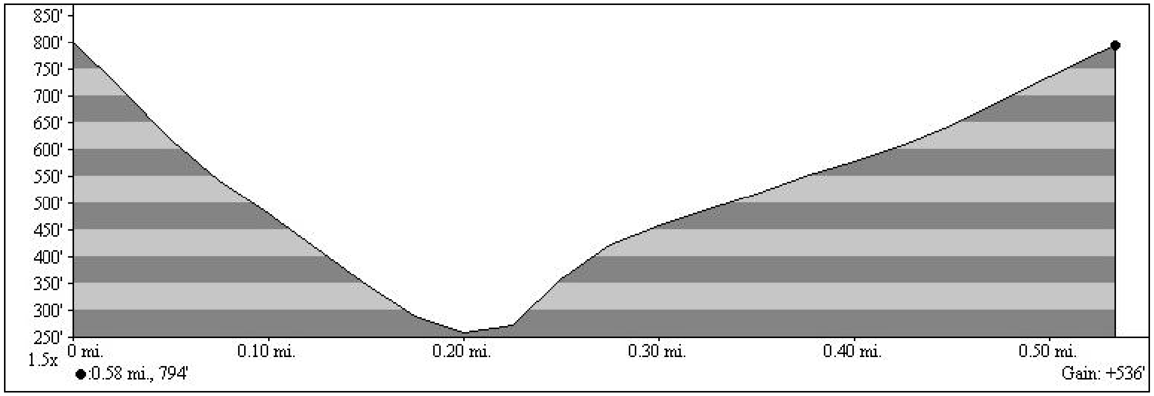


Figure 5-28. Kalama River Dam Cross Section

Inundated Area

The inundated surface area at full-pool elevation would be approximately 7,200 acres. The reservoir would be approximately 15 miles long.

Dam Size

The dam would be approximately 2,800 feet long by 560 feet high, including a 10-foot freeboard.

5.2.20.4 Water Sources and Availability

The drainage area at the Kalama River Dam and Reservoir site is roughly 150 square miles. USGS records indicate that average annual inflows to the reservoir could average on the order of approximately 600,000 acre-feet per year. Depending on the size of the Kalama River Reservoir and the required minimum releases below the dam, this inflow could provide a substantial component of the water availability at the site. Columbia River water would be diverted to this site downstream from Bonneville Dam. As presented in Table 5-35, the total Columbia River outflow at Bonneville Dam averages about 135,000,000 acre-feet per year. At the Kalama River Reservoir diversion site in the Columbia River, total flows would be significantly greater than the flows at Bonneville Dam as presented in Table 5-35 because of the substantial inflow from the Willamette River.

Table 5-35. Total Columbia River Flow at Bonneville Dam
(1000's of acre-feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	6,629	7,438	7,686	8,972	5,488	7,439	3,566	3,915	9,032	11,447	10,564	4,452	4,092	5,294	96,014
1930	6,762	7,438	7,686	5,899	7,304	7,135	3,872	4,192	8,702	10,758	10,204	4,802	4,257	5,429	94,440
1931	6,892	7,438	7,686	6,093	5,270	6,771	4,656	3,825	9,575	9,999	9,131	4,859	4,104	5,562	91,861
1932	6,794	7,438	7,686	6,455	5,398	9,960	7,123	9,579	19,857	16,903	13,236	6,007	5,510	6,132	128,076
1933	6,893	7,438	9,223	12,908	10,140	7,446	5,041	6,241	16,128	23,850	18,377	6,269	6,609	6,766	143,328
1934	8,417	10,029	17,438	21,101	14,309	12,534	9,256	9,704	17,791	10,546	12,205	4,640	3,951	5,676	157,598
1935	6,728	7,438	8,649	12,297	11,639	6,588	4,342	6,636	14,113	14,424	13,053	6,253	4,732	5,908	122,799
1936	6,795	7,438	7,686	7,354	5,427	7,809	3,981	7,344	21,154	13,847	10,677	5,389	4,333	5,640	114,874
1937	6,803	7,438	7,686	6,295	5,572	7,277	3,803	4,653	9,793	11,198	10,519	5,166	4,068	5,546	95,815
1938	7,045	7,438	8,515	13,663	7,837	11,234	6,706	7,858	21,064	16,495	12,634	4,991	4,274	6,126	135,879
1939	7,110	7,438	7,686	9,588	5,745	8,033	4,621	5,664	15,238	10,839	10,611	5,627	4,369	5,656	108,225
1940	6,982	7,438	8,010	8,695	7,115	11,257	5,273	6,546	13,848	12,141	9,754	4,904	4,165	5,562	111,692
1941	7,044	7,438	8,699	9,780	5,799	7,680	3,730	4,291	10,867	12,354	9,154	4,639	4,245	6,152	101,871
1942	7,143	7,438	11,392	13,359	7,195	6,743	4,342	6,121	13,622	16,602	13,388	6,213	5,421	6,005	124,983
1943	6,874	7,438	9,073	12,682	10,548	11,760	10,260	10,898	20,796	18,200	15,225	6,265	5,714	5,958	151,692
1944	6,876	7,438	7,775	9,417	5,552	6,421	3,635	3,803	8,928	10,332	8,814	4,588	3,837	5,542	92,959
1945	6,584	7,438	7,686	6,465	6,294	6,899	3,771	4,102	13,686	15,438	11,127	4,867	4,724	5,362	104,443
1946	6,908	7,438	7,917	10,819	9,031	11,925	6,724	8,630	21,848	16,480	13,878	6,222	5,099	6,312	139,230
1947	6,917	7,438	12,860	13,361	11,025	12,053	5,492	7,440	19,455	15,636	13,129	6,171	4,675	5,915	141,564
1948	9,701	9,137	10,573	13,758	8,129	9,712	5,534	8,190	23,633	37,110	15,654	6,203	6,565	7,243	171,142
1949	7,382	7,438	8,641	9,983	8,439	14,211	5,864	9,415	22,539	16,450	10,176	4,797	3,915	5,267	134,516
1950	6,899	7,438	7,842	10,777	11,829	15,223	8,282	8,862	19,075	25,284	16,932	6,255	6,079	6,543	157,320
1951	8,175	10,065	14,092	16,795	15,637	12,859	7,928	9,664	23,804	15,559	14,617	6,312	6,085	6,805	168,398
1952	9,136	7,850	11,026	12,676	10,084	10,664	8,765	10,318	24,152	16,132	11,902	5,866	4,625	5,759	148,956
1953	6,683	7,438	7,686	10,644	11,591	7,876	4,241	6,245	17,679	21,513	15,112	6,156	5,102	6,168	134,135
1954	7,256	7,519	10,054	11,793	11,621	10,227	7,021	7,776	19,997	22,635	16,878	7,264	6,593	9,817	156,450
1955	7,901	8,608	9,742	8,730	5,911	6,409	4,211	4,764	13,637	23,535	19,550	6,343	6,352	6,149	131,843
1956	7,958	9,414	14,136	17,774	10,135	14,365	8,455	12,071	28,263	26,156	15,780	6,295	5,670	6,356	182,828
1957	7,504	7,438	10,390	11,219	6,924	10,299	8,683	7,882	24,219	22,906	11,876	5,062	4,185	5,717	144,303
1958	7,039	7,438	8,084	10,822	10,787	10,562	5,349	8,731	22,012	19,008	10,962	5,035	4,538	5,711	136,079
1959	6,788	8,457	11,433	16,467	11,814	10,295	6,703	7,107	18,051	20,813	16,214	6,227	5,460	9,252	155,080
1960	11,479	10,520	12,503	12,161	8,265	9,843	9,324	8,717	16,078	16,730	13,249	6,118	4,333	5,811	145,131
1961	7,034	7,991	8,650	11,667	11,783	11,679	6,495	7,341	16,824	24,639	12,240	5,181	4,777	5,448	141,750
1962	6,788	7,438	7,745	11,419	6,935	7,544	7,884	9,142	16,031	14,786	12,881	5,680	5,020	5,645	124,938
1963	7,533	8,485	11,389	11,585	9,414	9,026	4,411	5,460	16,187	15,124	12,696	6,119	5,191	6,117	128,739
1964	6,466	7,438	8,061	11,327	7,584	7,154	5,651	6,614	15,478	24,287	18,357	6,134	5,892	6,865	137,307
1965	8,163	7,597	15,074	18,522	14,881	12,857	6,467	9,851	21,496	19,644	13,180	6,193	5,872	6,458	166,254
1966	7,465	7,662	9,679	12,453	6,936	7,839	6,650	5,790	14,607	12,439	13,272	6,211	4,845	5,513	121,360
1967	6,658	7,438	8,870	13,454	12,707	8,329	6,035	5,959	15,139	22,948	16,301	6,044	5,358	6,174	141,415
1968	7,319	7,658	9,728	12,611	11,041	10,199	3,484	5,450	12,906	16,449	15,047	6,075	5,422	7,561	130,952
1969	8,280	8,966	10,578	15,709	11,622	10,804	9,233	9,745	16,454	16,589	12,618	5,655	4,301	5,512	146,065
1970	6,870	7,438	8,216	13,077	10,489	8,183	3,999	6,085	15,704	19,022	10,011	4,678	4,090	5,270	123,133
1971	6,760	7,438	8,138	15,292	16,041	11,778	7,127	8,696	27,822	23,965	15,821	5,943	6,223	6,119	167,164
1972	6,722	7,541	9,711	14,444	14,831	21,566	9,707	7,476	25,185	27,740	17,256	6,566	6,602	6,741	182,087
1973	7,122	7,438	10,250	13,223	5,862	7,045	3,204	3,872	10,412	11,050	9,566	4,512	3,732	4,969	102,258
1974	6,632	7,438	12,500	21,539	16,052	14,371	9,074	10,864	24,884	28,449	20,300	6,305	6,560	6,664	191,633
1975	6,594	7,438	8,486	12,742	9,352	11,613	5,632	6,931	18,868	21,381	17,948	5,286	4,725	6,299	143,293
1976	7,850	9,598	16,174	16,525	11,843	11,057	8,831	8,598	23,612	15,610	16,390	7,467	7,492	10,625	171,673
1977	7,280	7,438	7,999	9,622	5,284	5,791	3,246	3,434	9,652	9,298	7,741	4,761	3,728	5,244	90,518
1978	6,285	7,438	9,929	11,429	8,223	12,432	6,154	7,405	18,139	15,345	13,970	5,697	5,037	6,197	133,681
Average	7,278	7,851	9,768	12,109	9,375	9,976	6,077	7,198	17,561	17,802	13,404	5,695	5,051	6,211	135,355
Maximum	11,479	10,520	17,438	21,539	16,052	21,566	10,260	12,071	28,263	37,110	20,300	7,467	7,492	10,625	191,633
Minimum	6,285	7,438	7,686	5,899	5,270	5,791	3,204	3,434	8,702	9,298	7,741	4,452	3,728	4,969	90,518

Except for the months of September and October, the water availability at Bonneville Dam can be determined as river flow in excess of the target flows specified at McNary and Bonneville dams in the 2000 BiOp. The target flows specified for the upstream McNary Dam were assumed to also be in effect for releases from Bonneville Dam. In September and October, the water availability at Bonneville dam was conservatively estimated as the same percentage of total flow availability as was available at Priest Rapids Dam.

The flow of the Willamette River at Portland averages about 33,000 cfs or 24,000,000 acre-feet per year. As a conservative assumption pending advancement of the Kalama River site to more detailed analysis, Columbia River water availability to the Kalama River Reservoir is assumed to be essentially from Bonneville Lake as presented in Table 5-36.

Table 5-36. Total Water Availability in Bonneville Lake (1000's of acre-feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	June	July	Aug1	Aug2	Sep	Total
1929	1,928	0	0	1,286	0	0	0	0	0	0	0	0	0	866	4,081
1930	2,386	0	0	0	362	0	0	0	0	0	0	0	0	1,102	3,851
1931	2,201	0	0	0	0	0	0	0	0	0	0	0	0	1,394	3,596
1932	2,242	0	0	0	0	2,274	0	1,843	3,870	1,432	938	56	0	1,206	13,861
1933	2,069	0	1,537	5,222	3,198	0	0	0	141	8,379	6,079	318	262	2,075	29,282
1934	3,855	2,591	9,752	13,415	7,367	4,848	1,520	1,968	1,804	0	0	0	0	1,034	48,155
1935	2,108	0	963	4,611	4,697	0	0	0	0	0	755	302	0	1,251	14,687
1936	2,243	0	0	0	0	123	0	0	5,167	0	0	0	0	668	8,202
1937	2,241	0	0	0	0	0	0	0	0	0	0	0	0	773	3,014
1938	2,472	0	829	5,977	895	3,548	0	123	5,077	1,023	336	0	0	1,275	21,556
1939	2,175	0	0	1,903	0	347	0	0	0	0	0	0	0	761	5,185
1940	2,435	0	324	1,010	172	3,571	0	0	0	0	0	0	0	579	8,090
1941	2,134	0	1,013	2,094	0	0	0	0	0	0	0	0	0	1,002	6,244
1942	1,999	0	3,706	5,673	253	0	0	0	0	1,131	1,091	262	0	911	15,026
1943	2,238	0	1,387	4,996	3,606	4,074	2,524	3,162	4,809	2,729	2,928	315	0	806	33,574
1944	2,072	0	89	1,731	0	0	0	0	0	0	0	0	0	1,015	4,907
1945	1,987	0	0	0	0	0	0	0	0	0	0	0	0	471	2,458
1946	2,302	0	231	3,133	2,088	4,239	0	895	5,861	1,009	1,581	272	0	1,366	22,976
1947	1,651	0	5,174	5,675	4,083	4,367	0	0	3,468	165	831	221	0	1,087	26,720
1948	5,253	1,699	2,887	6,072	1,186	2,026	0	454	7,647	21,639	3,357	252	218	2,684	55,375
1949	2,577	0	955	2,297	1,497	6,525	0	1,680	6,552	978	0	0	0	310	23,373
1950	2,110	0	156	3,091	4,887	7,537	546	1,127	3,088	9,813	4,634	304	0	1,714	39,007
1951	3,304	2,627	6,406	9,109	8,695	5,173	192	1,929	7,817	88	2,320	362	0	2,055	50,078
1952	4,387	412	3,340	4,990	3,142	2,978	1,029	2,583	8,166	661	0	0	0	780	32,468
1953	1,978	0	0	2,958	4,649	190	0	0	1,692	6,042	2,815	206	0	1,313	21,842
1954	2,471	81	2,368	4,107	4,679	2,541	0	40	4,010	7,164	4,580	1,313	246	5,658	39,259
1955	3,323	1,170	2,056	1,044	0	0	0	0	0	8,064	7,253	393	4	1,480	24,787
1956	3,197	1,976	6,450	10,088	3,192	6,679	720	4,335	12,276	10,685	3,483	345	0	1,341	64,767
1957	2,535	0	2,704	3,533	0	2,613	947	146	8,232	7,435	0	0	0	776	28,921
1958	2,033	0	398	3,136	3,845	2,876	0	995	6,025	3,537	0	0	0	955	23,801
1959	1,981	1,019	3,747	8,782	4,872	2,609	0	0	2,064	5,342	3,916	276	0	5,080	39,688
1960	6,672	3,082	4,817	4,475	1,323	2,157	1,588	982	91	1,259	952	168	0	1,186	28,752
1961	2,281	553	964	3,981	4,841	3,993	0	0	837	9,168	0	0	0	572	27,190
1962	1,988	0	59	3,733	0	0	149	1,407	44	0	583	0	0	770	8,734
1963	2,406	1,047	3,703	3,899	2,472	1,340	0	0	201	0	398	169	0	1,438	17,074
1964	1,735	0	375	3,641	642	0	0	0	0	8,816	6,059	183	0	2,307	23,758
1965	3,656	159	7,388	10,836	7,938	5,171	0	2,115	5,509	4,173	883	242	0	1,093	49,164
1966	2,376	223	1,993	4,767	0	153	0	0	0	0	974	261	0	841	11,588
1967	1,894	0	1,184	5,768	5,765	643	0	0	0	7,477	4,004	94	0	1,665	28,492
1968	2,344	220	2,042	4,925	4,099	2,513	0	0	0	978	2,750	125	0	3,113	23,110
1969	3,506	1,528	2,892	8,023	4,680	3,118	1,497	2,010	467	1,118	321	0	0	877	30,036
1970	2,066	0	530	5,392	3,547	497	0	0	0	3,551	0	0	0	0	15,582
1971	1,754	0	452	7,606	9,098	4,092	0	960	11,835	8,494	3,524	0	0	1,192	49,009
1972	1,714	103	2,025	6,758	7,888	13,880	1,971	0	9,198	12,269	4,958	616	255	2,041	63,677
1973	2,233	0	2,564	5,537	0	0	0	0	0	0	0	0	0	0	10,335
1974	1,841	0	4,814	13,853	9,110	6,685	1,338	3,129	8,898	12,978	8,003	355	213	2,107	73,324
1975	1,673	0	800	5,056	2,409	3,927	0	0	2,881	5,910	5,650	0	0	1,238	29,545
1976	2,812	2,160	8,488	8,839	4,901	3,371	1,096	863	7,626	139	4,093	1,517	1,145	6,473	53,521
1977	2,485	0	313	1,936	0	0	0	0	0	0	0	0	0	610	5,345
1978	1,365	0	2,243	3,743	1,281	4,746	0	0	2,152	0	1,672	0	0	1,326	18,529
Average	2,494	413	2,082	4,574	2,747	2,509	302	655	2,950	3,473	1,834	179	47	1,453	25,712
Maximum	6,672	3,082	9,752	13,853	9,110	13,880	2,524	4,335	12,276	21,639	8,003	1,517	1,145	6,473	73,324
Minimum	1,365	0	0	0	0	0	0	0	0	0	0	0	0	0	2,458
# Years of Avail. Water	50	17	41	44	35	35	13	21	31	32	31	25	7	48	50

5.2.20.5 Pre-Appraisal-Level Estimated Cost

The pre-appraisal-level estimated cost for the Rock Creek East Dam and Reservoir is shown in Table 5-37.

Table 5-37. Pre-Appraisal-Level Cost Estimate for Kalama River Dam and Reservoir*

Item	Cost	
Field (Direct) Costs		
1. Dam Structure	$ 196,000,000	
2. Spillway/Outlet Works	$ 20,000,000	
3. Pumping Plant, Pumps & Motors	$ 183,000,000	
4. Waterway (tunnel)	$ 176,000,000	
Sub-Total (Field Costs)	$ 575,000,000	
Allowances		
Mobilization (5% x Field Costs)	$ 28,750,000	
Sub-Total (Field Costs plus Mobilizaton)	$ 603,750,000	
Unlisted Items (15% of (Field Costs plus Mobilization))	$ 90,562,500	
Sub-Total (Field Costs plus Mobilizaton plus Unlisted Items)	$ 694,312,500	
Contingency (25% of (Field Costs plus Mobilizaton plus Unlisted Items))	$ 173,578,125	
Direct Construction Costs	$ 867,890,625	
Indirect Costs (20% to 35% of Direct Construction Costs)	$ 173,578,125	$ 303,761,719
Range Totals	**$ 1,041,468,750**	**$ 1,171,652,344**

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

5.2.20.6 Estimated Benefits

Benefits from the pumped storage water could include the following:

- Seasonal release of in-stream flows for fisheries
- Agricultural irrigation
- Municipal and Industrial (M&I) use
- Recreation

Anadromous Fish Flows

Water stored in the Kalama River Reservoir could be used to supplement Columbia River instream flows for anadromous fish. The 2000 BiOp flow targets are met at Bonneville Dam in every designated month. Since the water stored in the Kalama River Reservoir would only be released to the Columbia River downstream of Bonneville Dam, the benefit of any released water for anadromous fish flows would be minimal.

Agricultural Irrigation

An arbitrary distance of 50 miles for conveyance of stored water was used to estimate potential agricultural use. Beyond this distance, conveyance costs would make agricultural use uneconomical. The five-county area within the 50-mile radius of the site has a total of only 13,282 irrigated acres; therefore, the Kalama site would not provide a resource for a significant agricultural area.

M&I Water Supply

There would be minimal potential benefits from using Kalama River storage water for an M&I water supply. The Kelso/Longview and Vancouver metro areas are located within the 50-mile radius of the site, but local water supplies are expected to be sufficient to continue meeting future M&I water supply needs.

Recreation

There would be opportunities for recreational boating on the potential Kalama River reservoir. Development of a fishing resource would require fish stocking and fisheries management in the potential reservoir. If a fish ladder was included in the dam, there could be chinook and steelhead fisheries in the reservoir and upstream tributaries.

5.2.20.7 Waterway and Pumping Station Requirements

To provide a basis for comparison among reservoir sites, the pump capacity and waterway diameter and length requirements have been summarized in Table 5-2 in section 5.1.4 Pump and Waterway Sizes.

5.2.20.8 Regional and Local Geology

The Kalama River site is within the Columbia River drainage basin but, unlike the other sites, is not part of the Columbia Plateau. It is located along the west slopes of the Cascade Mountains near the north end of the Willamette Lowlands. Rocks exposed at this site include Quaternary volcaniclastic rocks (volcanic ash siltstone, tuff breccias, sandstones, and conglomerates), and, primarily, Oligocene to Eocene basaltic andesites. The volcaniclastic rocks are present in the valley floor upstream of the site. Basaltic andesites are the primary bedrock type and are massive to platy, weathered/oxidized, and may have thin flow interbeds of shale, tuff, or volcanic sandstones and conglomerates. Overburden is thin and consists primarily of Quaternary alluvium in the valley floor. Fracturing is common, and some minor faults associated with the Cascade Range are found within a 10-mile radius of the site (Schuster, 2002; Walsh et al., 1987; Washington Department of Wildlife, 1990). Mount St. Helens is approximately 25 miles northeast of the site.

5.2.20.9 Potential Environmental and Institutional Issues

The Kalama River site is located in Water Resource Inventory Area (WRIA) #27. A Level 1 Technical Assessment of WRIA 27 and 28 watersheds in 2000 indicated that the Kalama River watershed had low levels of urbanization and development and limited potential for water use conflicts (LCFRB, 2000). The Kalama River was not listed for water quality impairments in 2003 (Ecology, 2004). The Kalama River is used by chinook and coho salmon and steelhead trout. Fall chinook spawn below the Kalama Falls Hatchery. Summer steelheads spawn above the Kalama Falls Hatchery to river mile 36. Winter steelheads spawn below the Hatchery. Coho spawn throughout the Kalama River basin. (Kalama River Fish Habitat

Analysis Using the Instream Flow Incremental Methodology 1999) The proposed dam would be a barrier to fish passage unless a fish ladder or other were constructed at the dam.

There are no major structures in the Kalama River above the proposed dam site. The Kalama River Road is located in the Kalama River canyon and would need to be relocated, but there are no major traffic routes through the area of potential inundation. A transmission line crosses the potential reservoir site 0.8 mile above the dam site. The area around the potential reservoir site is forested and under timber production; there is no significant agricultural development in the reservoir area proper. There are no wildlife refuges designated in the potential reservoir area. The reservoir would inundate approximately 172 acres of NWI wetlands at full pool elevation.

The Washington State GAP Analysis database (WAGAP, 2005) was searched for federal or state listed threatened, endangered, candidate or sensitive species with predicted habitat or recorded occurrences in or near potential dam and reservoir sites. GAP predicted habitat maps were derived from determination of vegetative cover by analysis of satellite photography. Habitat in the Kalama River site is conifer forest dominated by Douglas fir surrounding a mixed riparian community along the river. Table 5-38 summarizes listed vertebrate species that have potential habitat in the area of the potential Kalama River dam and reservoir site.

Table 5-38. Listed Vertebrate Species With GAP Habitat in the Kalama River Site

Common Name	Scientific Name	Federal Status[1]	State Status[2]
Cascade torrent salamander	*Rhyacotriton cascadae*	NL	SC
Larch mountain salamander	*Plethodon larselli*	NL	SS
Van Dyke's salamander	*Plethodon vandykei*	NL	SC
Western toad	*Bufo boreas*	NL	SC
Bald eagle	*Halieetus leucocephalus*	T	ST
Lewis' woodpecker	*Melanerpes lewis*	NL	SC
Northern spotted owl	*Strix occidentalis*	T	SE
Townsend's big-eared bat	*Coryhorhinus townsendii*	NL	SC

Notes:
[1] T = Threatened; NL = Not Listed
[2] SC = State Candidate; SE = State Endangered; ST = State Threatened; SS = State Sensitive

Small animals with limited dispersal capacity and home ranges impacted by dam construction or inundated by the reservoir would be at greatest risk. Large mobile species and birds could disperse from the construction and inundation zones. Bats would generally not be impacted unless a dam or reservoir would cover or inundate a hibernaculum. Cascade torrent salamanders and the western toad have potential habitat that could be inundated by the reservoir; Larch Mountain and Van Dyke's salamander potential habitat extends close to the eastern end of the potential reservoir, but there are no observations of the species in that area. Bald eagle habitat extends along the western Columbia River and major tributaries, but the potential Kalama River dam and reservoir would not likely adversely affect bald eagles and the reservoir could provide new breeding and foraging habitat. Spotted owl habitat and possible breeding occurrences are located adjacent to, but not within the reservoir site. Townsend's big-eared bat potential habitat covers most of the state; however, GAP data do not indicate observations in the Kalama River site area.

5.2.20.10 Issues of Concern

Construction and operation of a dam and reservoir and related features at the Kalama River site would involve the following environmental and institutional issues of concern:

- The Kalama River is habitat for federally-listed anadromous fish species, including chinook salmon, coho salmon and steelhead trout. The dam would be a barrier to anadromous fish passage and the reservoir would inundate anadromous and resident fish habitat in the creek.
- Approximately 172 acres of NWI wetlands would be impacted, requiring a Clean Water Act Section 404 permit and mitigation.
- Kalama River Road would be inundated by the reservoir.
- A power transmission line would be inundated by the reservoir.
- Active logging operations for timber production would be inundated by the reservoir.
- Bald eagle and Northern spotted owl, federally-listed threatened species, have suitable habitat that would be inundated by the reservoir. Bald eagle is listed as threatened by the State of Washington. Northern spotted owl is listed as endangered by the State of Washington.

5.3 AQUIFER STORAGE SITES

In researching previous economic and technical studies of Columbia River water storage options, conjunctive management of surface and groundwater supplies and the development and operation of groundwater storage facilities to meet future water demands was found to have widespread interest and support. Included within the work scope of this pre-appraisal report is identification of opportunities for aquifer storage using Columbia River or major tributary water as source water. Descriptions of prospective aquifer storage locations, potential host aquifers, what years any locations were investigated, identification of proponents of any sites and who performed any investigations are included. A map identifying these locations and sites of current or inactive projects is also included.

With input from USBR, certain assumptions with respect to prospective aquifer storage sites were used in developing this study. These include:

- The area investigated in this study is within in the Columbia River Basin, within the State of Washington or northern Oregon, above the Columbia River Gorge, upstream to Grand Coulee Dam, excluding the Snake River above Lower Granite Dam.
- The maximum practical distance from the Columbia River (or major tributary) should not exceed 10 miles.
- The maximum lift from the river source to the storage area will not exceed 800 ft.

A literature search was conducted to identify prospective aquifer storage sites within the established criteria. In addition to the literature search, inquiries were made with agencies and individuals, which in the opinion of the investigators would have knowledge of aquifer storage projects or studies within the geographical area of interest. Published investigations and information personally communicated about aquifer storage sites were limited to a few small-scale pilot projects for municipal water storage projects.

5.3.1 Active Projects

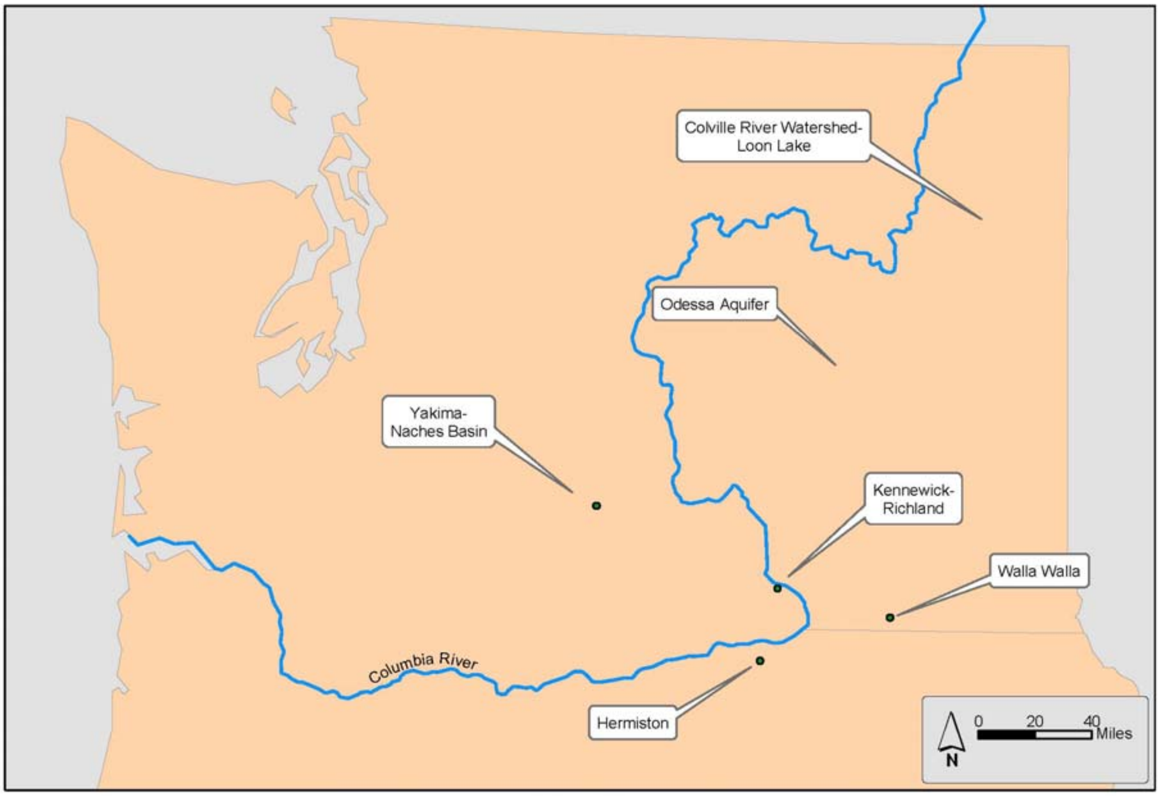
Although this pre-appraisal report focuses on large-scale prospective aquifer storage sites, the review of Columbia Basin aquifer storage projects identified the following small-scale but significant, active or demonstration projects in the study area:

- Cities of Kennewick and Richland
- City of Walla Walla
- City of Yakima
- City of Hermiston, Oregon
- City of Ephrata
- Royal City

In addition to these six aquifer storage projects, three other sites were identified that have potential for aquifer storage:

- Odessa Aquifer
- Colville River Watershed/Loon Lake Overflow
- Lower Umatilla Basin, Oregon

The locations of these active or potential aquifer storage sites are shown in Map 24.



Map 24
Columbia River Basin Storage Options Study
Aquifer Storage and Recharge Sites Overview Map

The cities of Walla Walla and Yakima currently have small-scale aquifer storage projects that inject modest amounts of treated municipal water, on the order of a few million gallons per day. In addition to Walla Walla and Yakima's projects, the City of Kennewick has investigated the feasibility of operating a small-scale aquifer storage project. The City of Hermiston, OR operated an aquifer storage demonstration project under the High Plains Groundwater Demonstration Program, jointly administered between USBR, USGS, USEPA, US Fish and Wildlife Service, the State of Oregon and the City of Hermiston between 1988 and 1996. Unexpected problems with respect to water quality, economic and institutional issues lead to this project being discontinued before full operation.

Brief summaries of these active projects are provided below. Information on each of the Washington projects is available from Washington Department of Ecology (WA DOE, 2001). Follow-up conversations with city personnel (Bouchane, 2005; Nicholson, 2005; Brown, 2005) provided supplemental information on the current status of aquifer storage programs.

5.3.1.1 Cities of Kennewick and Richland

Although the Tri-Cities area potable water supply is primarily treated water from the Columbia River, increased water demand due to projected growth is anticipated to exceed future availability during periods of peak summer demand. In 2000, the cities of Kennewick and Richland evaluated the feasibility of using Richland's Willowbrook Well in the Rock-Glade Watershed for a joint aquifer storage project to inject treated Columbia River water into the Wanapum Basalt Aquifer. The project goal was to inject treated water during periods of lower winter demand when river water availability exceeds demand, for withdrawal during periods of high demand. The evaluation was performed with the assistance of Aspect Consulting of Seattle. The cities determined that water quality in the Willowbrook Well was unsuitable for aquifer storage, and this project was discontinued (Bouchane, 2005; Germiat, 2005; Germiat and Flynn, 2005; WA DOE, 2001). However, the City of Kennewick, in cooperation with WRIA #31 watershed planners and with funding from Washington DOE, is conducting a feasibility assessment that will include modeling and an aquifer storage pilot-testing plan for recharging Columbia River water in the Wanapum Basalt Aquifer. This assessment has not yet been completed (Bouchane, 2005; Germiat and Flynn, 2005).

5.3.1.2 City of Walla Walla

The City of Walla Walla has had an active aquifer storage project in place since 1999. The City has two aquifer storage wells estimated to have a combined recharge capacity of approximately 3,000 gpm (4,840 acre-feet/year, if water is injected year-round). In practice, injection only occurs during winter months when supply exceeds demand. Although originally intended to have a recharge capacity of 500 to 600 million gallons per year, approximately 1.02 billion gallons (3,121 acre-feet) was injected in the 12-month period preceding March 2005 (primarily in winter months) in anticipation of ongoing drought conditions (Walla Walla City Council, 2005). Source water is treated Mill Creek water and is recharged via the two wells into the Grande Ronde Aquifer. The aquifer storage program has been very successful in providing conjunctive use storage and has reversed the trend of falling water tables in the immediate area (Nicholson, 2005; Walla Walla Watershed Planning Committee, 2004; Klisch and Banton, 2005; Price, 1960; WA DOE, 2001).

In 2004, the Hudson Bay Aquifer Recharge Project was initiated as a collaborative effort between the Walla Walla Basin Watershed Council and the Hudson Bay District Improvement Company, with funding and technical assistance from various sources and consulting assistance from Kennedy/Jenks Consultants. A test in April and May 2004 consisted of surface infiltration of Columbia River water into the shallow alluvial aquifer. Approximately 860 acre-feet were recharged during the 38-day period (8,260 acre-feet/year, if recharged continually) by means of three infiltration basins and a ditch. The results indicated that infiltration recharge to the shallow alluvial aquifer is feasible, although some water quality problems were identified, and further study was recommended (Walla Walla Basin Watershed Council, 2004).

5.3.1.3 City of Yakima

A pilot program conducted by the City of Yakima in 2000-2001 demonstrated that aquifer storage is feasible in the Ahtanum-Moxee Sub-basin of the Yakima Basin. One well was recharged with water treated to drinking water standards from the Naches River at a rate of approximately 1,200 gpm (1,936 acre-feet, if injected continually for one year) for 55 days, followed by 30 days of pumping at 2,000 gpm. Water was injected into and recovered from a sand and gravel aquifer in the upper Ellensburg Formation, a sedimentary bed that overlies the Wanapum Basalt. Approximately 70 percent of the water pumped was considered to be recovered from injected water. The pilot study indicated that a full-scale aquifer storage program would be feasible (Brown, 2005; City of Yakima, 2003; Waldo, 2000; Washington DOE, 2001).

A follow-up hydraulic aquifer model of a hypothetical aquifer storage program was prepared using MODFLOW in December 2002 (Golder, 2002). The model results were tentative but tended to support the feasibility of an aquifer storage project in the Naches Basin. No additional aquifer storage development has been conducted, although the City of Yakima has applied for a permit to develop an aquifer storage program. This program is projected to include two aquifer storage wells with injection rates of approximately 1,350 gpm to 2,250 gpm and could be implemented by 2008 or 2009.

5.3.2 Other Active Projects

This pre-appraisal investigation revealed two, small-scale, infiltration demonstration projects, specifically for groundwater recharge, that have been operated by the Cities of Ephrata and Royal City. Source water for both projects is treated municipal wastewater. The City of Ephrata's project, through its water reclamation plant, has a design capacity of 1.12 mgd or about 1,255 acre-feet/year. Royal City's project, through its wastewater treatment plant, has a design capacity of 0.25 mgd or about 280 acre-feet/year. Other small-scale infiltration projects using treated municipal wastewater as source water for groundwater recharge are planned by Spokane County and the City of Pullman/Washington State University (Washington DOE, 2000).

5.3.3 Potential aquifer storage Sites

The Odessa Sub-area, the Colville River Watershed/Loon Lake Overflow area and the Lower Umatilla Basin, Oregon have favorable characteristics for aquifer storage sites. These areas have had only limited evaluation and it is unknown at this time if they could meet permitting requirements by state agencies and Federal requirements pertaining to aquifer storage. The Odessa Sub-area has been significantly de-watered and aquifer storage has been identified as a potential solution.

5.3.3.1 Odessa Aquifer

The Odessa Aquifer is a basalt aquifer located in south Lincoln County, north Adams County, and southeast Grant County (Odessa Sub-area). The aquifer is an interbasin region of the much-larger Wanapum Basalt. It has been extensively used for irrigation water, and the water table has been in decline since much of the region was converted from dry farming to irrigation in the late 1960s and 1970s (Luzier et al., 1968). Recharge of the Odessa Aquifer has been discussed in connection with recent water initiatives, including the recent Columbia River Initiative, and it appears that local interest is favorable (Family Farm Alliance, 2004; Washington DOE, 2005). However, the concept of aquifer recharge has not been thoroughly evaluated for technical feasibility. The aquifer consists of alternating layers of basalt flows, rubble contacts, and sedimentary interbeds, with most groundwater production coming from the rubbly contacts and sedimentary interbeds (Luzier et al., 1968). Because hydraulic connection with the surface is restricted, it is likely that an aquifer storage project would require recharge by means of injection wells. It is likely that existing wells could be retrofitted at reasonable cost to serve as injection/recovery wells.

Although most of the aquifer is far from the Columbia River, its northern edge extends to the Columbia River in the southern Roosevelt Lake area. Because the aquifer gradient is northward in this area, source water for recharge from the Columbia River/Roosevelt Lake would likely need to be pumped at least 10 to 20 miles to a recharge area that is south of the groundwater divide between northward and southward groundwater flow gradients.

An alternative proposal, where feasible, would implement water conservation projects (lining of canals and pipelines) and divert some or all of conserved surface waters to the Odessa Sub-area for irrigation use. Irrigators who currently use groundwater would idle some or all of their irrigation wells, reducing demand on the aquifer, allowing natural infiltration to help replenish the aquifer creating in effect, an in-lieu recharge credit (Washington DOE, 2003 and 2005). The U. S. Bureau of reclamation is currently conducting the "Odessa Sub-area Special Study, Continued Development of the Columbia Basin Project", to specifically to address declining ground water levels in the Odessa Aquifer.

5.3.3.2 Colville River Watershed near Loon Lake

Spring overflow from Loon Lake in east Stevens County is diverted into the headwaters of Sheep Creek, a tributary to the Colville River, which is, in turn, a tributary to the Columbia River. This area is in the recharge area for the Lower Aquifer, a glacial outwash feature within the Colville River Basin. WRIA #59 has conducted a preliminary evaluation of the potential for recharging some or all of the overflow runoff from Loon Lake into gravel pits or infiltration channels (Family Farm Alliance, 2003; Longpre and Ely, 2003; Kahle, 2003). This proposed project would not involve direct pumping from the Columbia River to recharge the aquifer. It is mentioned in this study because it would divert some water that otherwise would flow into the Columbia River via Sheep Creek and the Colville River. The project's location is many miles from the Columbia River and would involve relatively small quantities of water.

5.3.3.3 Lower Umatilla basin, Oregon

The literature search located a published report by James M. Montgomery Consulting Engineers (1990), that described the feasibility of recharging up to 16,000 acre-feet annually through infiltration, into a shallow glacial-fluvial aquifer, in the Lower Umatilla Basin in Oregon. This project proposed using existing gravel pits and unlined canals as infiltration sites and wells to recover the recharged water. Further research failed to determine if this proposed project was ever developed.

5.3.4 Conclusion

Municipal and irrigation stakeholders indicate a high degree of interest in regional, cooperative opportunities of artificial recharge for aquifer storage and banking. However, this pre-appraisal report identifies no specific proposed large-scale, long-term aquifer storage projects. A few active, but small-scale municipal storage projects are either injecting municipal water treated to drinking water standards, or infiltrating treated wastewater for aquifer replenishment. Locales described in this pre-appraisal report appear to have the necessary hydrogeological conditions for long-term, large-scale aquifer storage but detailed hydrologic studies will be necessary to determine their feasibility. In addition, there are several conditions and requirements that must be addressed prior to implementing any aquifer storage project. Among them are well construction costs, injection and recovery costs, water right issues, water quality issues, conveyance issues and permitting requirements by regulatory authorities as well as other institutional and environmental issues.

6.0 OPINION OF CAPITAL CONSTRUCTION COST FOR IDENTIFIED FEASIBLE OFF-CHANNEL STORAGE SITES

6.1 INTRODUCTION

This section summarizes the opinion of capital construction cost and potential water storage capacity for each of the eleven potential storage sites. Section 5 incorporates a more detailed breakdown of specific capital construction cost components for each site. The pre-appraisal-level cost estimates presented in section 5 were developed to provide relative cost information for all identified potential water storage sites given the siting and selection assumptions presented in Section 5. The opinion of capital construction cost is derived from a variety of sources, including estimating information developed by MWH on other similar projects, industry costing standards and government estimating principles. For pre-appraisal-level planning purposes, the opinion of probable cost should be considered to have an accuracy of plus 40 percent to minus 25 percent.

Table 6-1 provides an evaluation of capital cost and cost per acre-foot of stored water. The unit cost of storage ($ per acre-foot) varies significantly among the eleven options from a high of $2,500 to a low of $400.

6.2 COST ESTIMATE ASSUMPTIONS

The assumptions used to develop the opinion of probable capital construction cost were based upon construction of a dam, reservoir and appurtenances to supply water to the reservoir for storage, but not the cost of distributing the stored water for offsite use. It was assumed in all cases that water would be pumped from a site on the Columbia River to a new off-channel reservoir site. The conveyance system component included tunnels as appropriate. Dam cost is a function of height and length for a new embankment (central core rockfill) dam structure. Water supply conveyance costs are dependent upon the assumed distance from where Columbia River water would be diverted and the length of the pump and piped conveyance system to deliver the water to the reservoir. Pumping and waterway costs were based upon pumping lift required and the flow, as well as size, of the waterway to satisfy the required flow.

6.3 IMPACT OF CAPITAL COST

The real cost of water is highly dependent on the value of the water provided and the ultimate use. Sites with a low cost per acre-foot may not be in a geographic location where the water has a significant value because of surrounding land use, agricultural patterns and/or population. In contrast, water with a high beneficial use and value (municipal/industrial or high value crops) may support a much higher capital development cost. These are decisions and analysis beyond the scope of this study.

Table 6-1. Pre-Appraisal Level Cost Estimates of Potential Columbia River Off-Channel Storage Sites*

Site	Maximum Water Level (feet)	Total Storage (acre-feet)	Active Storage (acre-feet)	Time to Fill Active Storage[1] (months)	Pump Capacity (cfs)	Waterway Diameter (feet)	Waterway Length (miles)	Cost Estimate Millions[2] ($)	$/AF[2] ($)	Cost Estimate Millions[3] ($Millions)	$/AF[3] ($)
Ninemile Flat	2100	1,030,000	930,000	4	3,900	18	0.86	$1,293	$1,260	$1,455	$1,410
Hawk Creek	2000	1,550,000	1,400,000	4.8	4,800	20	1	1,444	930	1,624	1050
Goose Lake	1750	3,720,000	3,350,000	8.7	6,400	23	0.7	2,967	800	3,340	900
Foster Creek	1700	1,340,000	1,210,000	4.4	4,500	20	1.75	2,976	2,220	3,348	2,500
Mission Creek	1600	470,000	420,000	4	1,700	12	7.7	1,235	2,630	1,390	2,960
Moses Coulee	1400	4,130,000	3,720,000	9.4	6,500	23	2.58	1,891	460	2,127	520
Sand Hollow	1200	1,230,000	1,110,000	4.2	4,400	19	2.38	971	790	1092	890
Crab Creek	700	2,650,000	2,390,000	6.8	5,800	22	2.5	1,703	640	1,915	720
Alder Creek	700	330,000	300,000	4	1,200	10	1.25	491	1,490	552	1,670
Rock Creek East	900	1,000,000	900,000	4	3,700	18	0.58	1,195	1,200	1,345	1,350
Kalama River	800	1,185,000	1,070,000	4.1	4,300	19	6.1	1041	880	1172	990

*Pre-Appraisal Level Cost Estimates for alternative comparison purposes only.

1 Based on continuous pumping at pump capacity.

2 Based on 20% of Direct Construction Costs

3 Based on 35% of Direct Construction Costs

7.0 EVALUATION CRITERIA DEVELOPMENT FOR ADDITIONAL INVESTIGATION

The intent of this section of the report is to develop a catalog of potential site/project evaluation criteria that can be used as a basis for analyzing the potential storage options and sites. The objective is not to provide the analysis, but only to develop a reasonable range of criteria that can be used by others in evaluating each alternative site. Not all criteria will be applicable to every site developed in Section 5. Criteria will need to include both objective and subjective elements in order to cover the full range of concerns, some of which cannot be quantified or easily measured.

In addition to identifying the list of evaluation criteria, it will be necessary to assign some level of ranking to each element to allow the various options to be differentiated. The ranking or weighting of criteria can become rather complex. One method to simplify the analysis is to establish the criteria as objectives and rank the criteria on how well the objectives are met by each alternative using a number of specific subcriteria. The objectives, based upon Federal guidelines for water resources planning, would include:

- Completeness
- Effectiveness
- Efficiency
- Acceptability

For each storage option a relative ranking score can be assigned for the subcriteria ranging from very low to very high (very low, low, medium, high, and very high) for each of the criterion. The overall ranking conformance with the objective can then be used to determine, along with other information, if a storage site option should be considered further in the planning as additional mainstem Columbia River water storage.

7.1 COMPLETENESS CRITERION

Completeness is a determination of whether an option can include all elements necessary to realize planned effects (can a complete and workable project be developed). It also is an indication of the degree that the intended benefits of the plan depend on the actions of others or other actions that would need to be implemented (e.g., new irrigated agricultural areas). For the storage options, the subcriteria described below are believed only to become important in estimating the relative completeness of the proposed siting concept. Each concept presented is considered complete as proposed. Its relative completeness ranking ranging from low to high will primarily depend on the degree of uncertainty (or reliability) of achieving the intended objectives and adequately mitigating significant adverse impacts. Concepts that received the highest relative ranking for this criterion would be considered as best satisfying the criteria. Siting concepts that received the lowest relative ranking are ranked low because it would provide very little benefit in meeting the overall planning objective.

Subcriteria under completeness would include:

Authorization – Consistency with basic objectives (area, size, etc.) of the study and how it addresses the institutional and regulatory aspects of the management of the Columbia River drainage.

Reliability – A measurement of a site's capability to provide, over the project life on a consistent basis, the specific and sustained benefits for which it was intended. It would include what future actions, other than normal and identified operation and maintenance, would be required for full and successful implementation of the option.

Physical Implementability – Can the site be developed, constructed and operated as proposed without resorting to heroic efforts or undue costs. While all of the selected sites have the opportunity for development, there are conditions or challenges that differentiate the sites.

Environmental Resources – This subcriterion assesses the relative ability of an option to be implemented to either avoid potential adverse environmental impacts or successfully mitigate for unavoidable adverse impacts.

Water and Related Resources – This subcriterion is intended to determine if the option can be implemented to mitigate unavoidable impacts on other water users (is the water available for storage), hydroelectric power generation, flood control, recreation, and/or related resources.

Hydraulic Conditions – This subcriterion measures the ability of a proposed site to avoid adverse hydraulic impacts on areas surrounding or adjacent to a storage site. Inundation of areas associated with the construction of new storage resources is unavailable and little can be done to avoid loss of these areas. Mitigation to avoid soil erosion and loss of significant vegetation needs to be assessed. Property acquisition and management of the storage areas need to be considered.

All of the options would result in some seasonal change in flow conditions downstream of the storage area or diversion. As discussed in Section 5, Columbia River water is generally available in fall and winter months. The criteria evaluations will need to assess the system impact of removing instream water for offstream storage during these periods on fish, wildlife and other economic and social related activities.

Cultural Resources – This subcriterion measures the options' adverse impacts on known and potential historic and/or cultural resources and the ability to successfully mitigate for unavoidable adverse impacts.

7.2 EFFECTIVENESS CRITERIA

Effectiveness is the extent to which the option satisfies the objectives without creating adverse impacts that cannot be successfully mitigated. The primary objective of the storage project was to make additional water available for the five major uses. These uses include agriculture, fish and wildlife, municipal and industrial water supply, recreation and power generation. Each option has the potential of meeting one or more of these objectives to various degrees. Seasonal supplementation of instream flow, either by reducing diversion or return flow to the river, can satisfy a variety of these needs. The degree to which a specific criterion is met involves a decision that will need to be made through the project reviews.

The project requirement to reliably store and use, on an annual basis, a minimum of 300,000 acre-feet of Columbia River water will be overall objective of the project. How the water is divided (see section 3) among the defined uses and what the secondary benefits (instream flows) will be for each option will be developed as part of the criteria assessment.

7.3 EFFICIENCY CRITERION

Efficiency is a measure of how effectively an option can meet the objectives while realizing specified goals to maintain cost control and protect the environment. Both direct water supply reliability cost (dollar per acre foot of water yield) and secondary costs and values (ecosystem protection, flood control, fish passage, habitat improvement, etc.) provided by a project alternative will need to be assessed and rated. A higher cost project may have a very high combined primary and secondary benefit and thus may, in terms of cost benefit, rank higher in site rating.

7.4 ACCEPTABILITY CRITERION

Acceptability is the workability and viability of a plan with respect to its potential acceptance by other Federal agencies, State and local governments, and public interest groups and individuals. At the current stage of plan formulation of this type of water storage project, little is known about the ultimate likelihood for Federal agency acceptance or non-Federal sponsorships. Much of the acceptability of additional offstream storage will depend on two factors. The first major factor is the cost of water to the consumer and its ultimate demand. Excessively high costs for new storage and delivery will have a dampening effect on the willingness to support and pay for a major water supply project. The second major factor will be the impacts, positive and/or adverse on fish, wildlife and recreation. This is especially true for anadromous fish movement, given the very controversial environmental and institutional positions that have been taken on the issue. Other factors that may come into the decision-making process are water rights and interstate issues regarding water storage, the economics of expanded irrigated agriculture in Washington State, demand for hydropower given the current energy shortage and other social, cultural and economic concerns, issues and opportunities.

Acceptability, by its nature, is a subjective issue and will require consensus building and negotiation to arrive at a true representative position.

7.5 SUMMARY

The intent of this section of the report is only to define potential criteria for assessing the future analysis of a Columbia River offstream water storage project. The recommended criteria are presented in the form of general objectives to be obtained with specific subcriteria under each objective that would be applicable to this evaluation. The subcriteria discussed are not intended to be all-inclusive and should be further developed as part of the planning process.

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APPENDIX A - CONTACT SUMMARIES BY AGENCY/GROUP

U.S. Bureau of Reclamation
Columbia River Basin - Study of Alternative Storage Sites
Contract No.

Organization and Contact Name	MWH Rep	Type of Contact (Legend #)	Contact Date	Information Requested	Comments
USBR Pat McGrane	JCH	1	7/20/2005	Water availability study info	Suggested several contacts for additional information.
Columbia Basin Project Manager Bill Gray	LLS	1	7/21/2005	Water availability study info	He mentioned Harza did an investigation on pumped storage at Banks Lake, Mid-Columbia.
USACE Ken Howdy	LLS	1	7/21/2005	study titled "Pumped Storage in the Pacific Northwest" Jan 1976	Found this contact from web site. Waiting for return phone call, left several messages.
USGS L. Fuste, Information Officer	GWQ	1	7/21/2005	ASR studies, rpts of potential sites	
WA DOE B. Walsh, Env Planner	GWQ	1	7/25/2005	ASR studies/investigations	Left voice message, waiting for return call.
Aspect Consultants M. Shaffer, Hydrogeologist	GWQ	1	7/26/2005	ASR studies/investigations of potential sites	Shaffer served on the committee presenting recommendations to WA legislature on codification of ASR regulations and statutes.
S. Columbia Basin Irrigation Dist Shannon McDaniel - Mgr	LLS	1	7/28/2005	Water availability study info	He mentioned a report Harza did (1985-88) Coleville Indian Reservatin, Chief Joseph Dam and an investigative report that USBR did in 1947 for Foster Creek
E. Columbia Basin Irrigation Dist Dick Erickson - Manager	LLS	1	7/28/2005	Water availability study info	Sites they looked at (more for canal operations than storage) were Warden-Coulee and Rocky-Coulee re-reg reservoirs. USBR did feasibility on Warden-Coulee.
Quincy-Columbia Basin Irrigation Dist Garth Gunter	LLS	1	7/28/2005	Water availability study info	Was aware of the CRI work but couldn't think of any additional info to pass along.
Quincy-Columbia Basin Irrigation Dist Darvin Sales - Manager	LLS	1	7/28/2005	Water availability study info	Couldn't think of any additional info to pass along.
ASR Systems, Consultants T. Morris, Consultant	GWQ	1	7/29/2005	ASR studies/investigations	Morris frequently lectures on ASR.
Aspect Consultants S. Germiat, Consultant	GWQ	1	8/1/2005	ASR studies/investigations	Earlier contact w/Shaffer suggested contacting Germiat because of his ASR feasibility study for City of Kennewick
WA DOE G. O'Keefe	GST	1	8/4/2005	Water availability study info	
WA DOE K. Ensenat, Env Planner	GWQ	1	8/5/2005	ASR studies/investigations	Returned call left for B. Walsh, not knowledgeable in ASR activities, contact J. Covert
USBR Boise L. Wuttke	GST	1	8/17/2005 8/22/2005	Contract Time extension & status	Contact N. Ries to discuss contract extension.
USBR Boise N. Ries	GST	1	8/18/2005 8/23/2005	Spreadsht of proposed sites; Contract extension & grdwater sites	
WA DOE J. Covert	GWQ	1	8/22/2005	ASR studies/investigations	Researched the Columbia Basin GWMA with no results
City of Kennewick B. Bouchane, Engineer	P Naylor	1	8/30/2005	ASR Projects in Columbia Basin	Familiar with 2001 ASR joint project on Willowbrook Well w/City of Richland.

Legend:
1. Phone
2. Fax
3. Email
4. Letter

U.S. Bureau of Reclamation
Columbia River Basin - Study of Alternative Storage Sites
Contract No.

Organization and Contact Name	MWH Rep	Type of Contact (Legend #)	Contact Date	Information Requested	Comments
City of Walla Walla F. Nicholson, Engineer	P Naylor	1	8/30/2005	ASR Projects in Columbia Basin	Familiar with City's ASR program that's been in place since 1999.
City of Walla Walla F. Nicholson, Engineer	P Naylor	1	8/30/2005	ASR Projects in Columbia Basin	Familiar with City's ASR program that's been in place since 1999.
City of Yakima D. Brown, Engineer	P Naylor	1	8/30/2005	ASR Projects in Columbia Basin	Familiar with City's ASR pilot program conducted in 2000-2001.
USBR Boise J. Hecht, Librarian	GWQ	1	9/2/2005	Request for library listing of ASR projects	Referred geologist based at Grand Coulee for additional info. Kayti Didricksen
USBR Grand Coulee K. Didricksen, Geologist	GWQ	1	9/8/2005	ASR studies/investigations	Was only aware of the smaller scale municipal ASR projects.

Legend:
1. Phone
2. Fax
3. Email
4. Letter

10/17/2005

MWH

TELEPHONE LOG

Persons Contacted:	Gerry O'Keefe	Project Name:	Columbia River Storage Study
Affiliation:	Washington DOE	Project Number:	1004446
MWH Rep.:	Glenn S. Tarbox	Date:	August 4, 2005
Copies to:	Project Team	Phone No.:	360 407 6640
Subject:	Political connections re the study		
X	*This call was initiated*	Time of Call:	8:45 am
	This call was received	Call Duration:	25 Mins.

Notes: Gerry returned my call placed on July 28, 2005.

Q. Do you have any reports of previous studies?
A. No.
Q. Who or what political interests are behind the study?
A. Gerry is "ramrod" representing DOE interests. Interested parties include Governor Gregoire, Gerry's boss, Jay Manning, Director of WA DOE and two gubernatorial staffers, Keith Phillips and Tom Fitzsimmons. Gregoire is familiar w/ National Research Council's (NRC) report, "Managing the Columbia River: Instream Flows, Water Withdrawals, and Salmon Survival," dated March 31, 2004. It lists four major pathways for water supply enhancement from the Columbia, modifications to projects on the mainstem, off-stream storage reservoirs, Canadian cooperation to reshape flows and conservation. The Governor understands the economical benefits to the state of increased water supplies to the ag community and the political advantages of constructing new CIP's in eastern part of state.

I gave Gerry a thumbnail sketch of where we are in the project and mentioned that MWH will be suggesting a meeting with USBR and DOE to discuss project status and solicit opinions of our proposed ranking criteria and seek input from the state and fed as well.

Action Items:

- Obtain and upload copy of NRC report onto the MWH ftp site ASAP (gst, jch)
- Team members review NRC report and derive information apropos their portions of the MWH draft report

MWH

TELEPHONE LOG

Persons Contacted:	Lisa Wuttke	Project Name:	Columbia River Storage Assessment
Affiliation:	USBR Boise	Project Number:	10044446
MWH Rep.:	Glenn Tarbox	Date:	August 17/22, 2005
Copies to:		Phone No.:	208 378 5047
Subject:	Contract time extension and project status.		
X	*This call was initiated*	Time of Call:	4 p.m.
Call back	*This call was received*	Call Duration:	45 mins.

Notes:

- **Provided a briefing on project status and that I had been awaiting a call back from Norbert Ries.**
- **Discussed need for a contract extension. At first she was going to contact Norbert to discuss. Then she asked me to discuss it with Ries when we finally made contact. She seemed not to mind any adjustments. It would be up to Norbert.**
- **I raised the potential for a joint meeting among USBR, WA DOE and MWH to make a status update presentation and to discuss proposed MWH screening criteria to be recommended in the report.**

Action Items:

- **Tarbox follow through with Ries.**

MWH

TELEPHONE LOG

Persons Contacted:	Norbert Ries	Project Name:	Columbia River Storage Assessment
Affiliation:	USBR Yakima	Project Number:	10044466
MWH Rep.:	Glenn Tarbox	Date:	August 18/23, 2005
Copies to:	BWQ, BDL, JCH, ETC, LLS, MMP	Phone No.:	509 575 5848
Subject:	Spreadsheet of proposed sites; contract extension and groundwater sites.		
X	*This call was initiated*	Time of Call:	12:30 p.m.
Call back	*This call was received*	Call Duration:	45 mins.

Notes:

- **Discussed MWH study parameters for identifying potential sites.**
- **Norbert will discuss w/ Gerry O'Keefe and call back w/ their joint comments re the list.**
- **I requested a one-month extension of time to October 15th for draft report. Norbert will also discuss it with O'Keefe and let us know.**
- **Inquired of any known aquifer studies or potential sites of >300,000 AF. He knew of none but suggested we look at recharging of Odessa Aquifer. He will also inquire of O'Keefe.**
- **He has heard talk about a super sized project known as Paradise Valley near Quincy returning discharges near Wenatchee (Norbert thinks he passed along that tip to Ed Cryer. Contact Dwayne Unland at Nakty Corp. 509 575 8393).**
- **He agrees that any pumped storage sites need to have >300,000 AF first and PS component is secondary. One of the most important elements of added storage is to provide supplemental flows during periods when irrigation water is turned off because of fish release demands.**
- **I proposed a possible meeting w/ USBR and DOE during first week of October with the draft submittal to follow by October 15th. He will discuss w/ O'Keefe.**

Action Items:

- **Tarbox coordinate w/ Norbert on schedule extension, list comments and future joint meeting dates and time.**
- **Cryer/Liming contact Unland @ Nakty.**
- **Quinn follow-up on Odessa Aquifer.**

MWH

TELEPHONE LOG

Persons Contacted:	Lisa Wuttke	Project Name:	Columbia River Storage Assessment
Affiliation:	USBR Boise	Project Number:	10044446
MWH Rep.:	Glenn Tarbox	Date:	August 17/22, 2005
Copies to:		Phone No.:	208 378 5047
Subject:	Contract time extension and project status.		
X	*This call was initiated*	Time of Call:	4 p.m.
Call back	*This call was received*	Call Duration:	45 mins.

Notes:

- **Provided a briefing on project status and that I had been awaiting a call back from Norbert Ries.**
- **Discussed need for a contract extension. At first she was going to contact Norbert to discuss. Then she asked me to discuss it with Ries when we finally made contact. She seemed not to mind any adjustments. It would be up to Norbert.**
- **I raised the potential for a joint meeting among USBR, WA DOE and MWH to make a status update presentation and to discuss proposed MWH screening criteria to be recommended in the report.**

Action Items:

- **Tarbox follow through with Ries.**

MWH

TELEPHONE LOG

Persons Contacted:	Ken Howdy (sp?)	Project Name:	Columbia River Storage Options
Affiliation:	USACE, NW Division	Project Number:	1004446
MWH Rep.:	L. Salton	Date:	7/21/05
Copies to:	file	Phone No.:	503-808-3710
Subject:	Water Availability Study Information		
X	*This call was initiated*	Time of Call:	2:30pm
	This call was received	Call Duration:	2 mins.

Notes:

I found this contact number on the USACE NW Division web site. I've left 2 messages trying to find out how to obtain a study they did in January 1976, titled "Pumped Storage in the Pacific Northwest". I'm still waiting for him to call me back, this report may already be in the library......

MWH

TELEPHONE LOG

Persons Contacted:	Norbert Reis	Project Name:	Columbia River Storage Options
Affiliation:	USBR Yakima	Project Number:	10044466
MWH Rep.:	Brian Liming	Date:	August 23, 2005
Copies to:	GWQ, GST, JCH, ETC, LLS, MMP	Phone No.:	509 575 5848
Subject:	Maximum Desired Outlet Capacity from Storage Sites		
X	*This call was initiated*	Time of Call:	4:30 p.m. Mountain Time
Call back	*This call was received*	Call Duration:	15 mins.

Notes:

- **I asked Norbert if the USBR has a desired maximum outlet capacity associated with any of the storage sites.**
- **Norbert stated that the USBR would like to operate a storage site on an annual cycle rather than on a monthly or weekly cycle. He listed a number of different release options the USBR would like to have including: a) allow the remainder of the Columbia Basin Project to be completed and operated (3 acre-feet x 500,000 acres); b) release agricultural water to irrigation districts throughout the irrigation season (e.g Yakima basin could use 2,500 cfs); c) provide fish target flows through supplementation; d) provide M&I water throughout the year to communities demonstrating needs; e) generate power by releasing the water**
- **Norbert considers power generation a secondary purpose, a side benefit to releasing water for other purposes or to meet other needs**
- **Norbert is most interested in the larger sites MWH has identified on the sites table**

Action Items:

- **Incorporate Norbert's feedback into the draft report as applicable**

MWH

TELEPHONE LOG

Persons Contacted:	Darvin Sales	Project Name:	Columbia River Storage Options
Affiliation:	Quincy-Columbia Basin Irrigation District	Project Number:	1004446
MWH Rep.:	L. Salton	Date:	7/29/05
Copies to:	file	Phone No.:	509-787-3591
Subject:	Water Availability Study Information		
	This call was initiated	Time of Call:	1:38
X	*This call was received*	Call Duration:	

Notes:

Darvin is the manager and was returning a call I had made yesterday. I spoke with Garth Gunter (see phone memo from 7/28) and he passed along my questions to Darvin. He left a message that he was not familiar with any additional sites or studies.

MWH

TELEPHONE LOG

Persons Contacted:	Dick Erickson	Project Name:	Columbia River Storage Options
Affiliation:	E Columbia Basin Irrigation District	Project Number:	1004446
MWH Rep.:	L. Salton	Date:	7/28/05
Copies to:	file	Phone No.:	509-488-9671
Subject:	Water Availability Study Information		
X	*This call was initiated*	Time of Call:	3:30pm
	This call was received	Call Duration:	15 mins.

Notes:

Dick Erickson is the Secretary who signed the MOU for the Columbia River Initiative (CRI). He was aware of the studies the USBR did back in the 70's at Foster-Coulee, Goose Flats and Barker Canyon sites. He said the sites they had looked at, more for canal operations than for storage were Warden-Coulee Re-reg Reservoir and Rocky-Coulee Re-reg reservoir, both only a couple thousand acre-feet. USBR did a feasibility report on the Warden-Coulee site about 5 years back, but no feasibility has been done on the Rocky-Coulee site.

MWH

TELEPHONE LOG

Persons Contacted:	Bill Gray	Project Name:	Columbia River Storage Options
Affiliation:	Manager, Columbia Basin Project	Project Number:	1004446
MWH Rep.:	L. Salton	Date:	7/21/05
Copies to:	file	Phone No.:	509-754-0214
Subject:	Water Availability Study Information		
X	*This call was initiated*	Time of Call:	2pm
	This call was received	Call Duration:	15 mins.

Notes:

I had a conversation with Bill Gray, Manager Columbia Basin Project. He mentioned that Harza did an investigation on pumped storage at Banks Lake, Mid-Columbia, a few years back. This may be in the library as well, if not, I can try to search our archives to see if I can find something. Bill also mentioned the Foster Creek and Goose Flats sites. He did say though, that these sites had really small storage potential.

This fellow is the BR librarian and appears to be helpful

----- Forwarded by Edwin T Cryer/User/Americas/Montgomery Watson on 07/26/2005 03:33 PM -----

Mr. Edwin T. Cryer, Vice President
Mr. George W. "Bill" Quinn, P.E.
MWH Americans, Inc.
671 East Riverpark Lane, #200
Boise, ID 38706

Gentlemen:

Per our conversation this afternoon, my contact information is listed below.
I am in the office Tuesday and Wednesday, July 26 and 27.
I will then be out-of-office through Monday, August 1.
I will be in office at least through August 12.
The following week I am pencilled to be out-of-office.

If you send me an e-mail listing the reach of the Columbia River (from-to), including the desired tributaries, I can assemble from my master library listing the reports, by Reclamation and by other agencies, regarding our projects within that area.

I understand this is essentially an open-end research project on your part, but the more specificity you can provide, the fewer listings (and thus documents) you will have to review.

John Hecht

John Hecht
Technical Writer/Editor (Natural Resources)
Pacific Northwest Region
U.S. Bureau of Reclamation

e = jhecht@pn.usbr.gov
p = 208-378-5091

1150 N. Curtis Road, Suite 100
Boise Idaho 83706-1234

MWH

TELEPHONE LOG

Persons Contacted:	Shannon McDaniel	Project Name:	Columbia River Storage Options
Affiliation:	S. Columbia Basin Irrigation District	Project Number:	1004446
MWH Rep.:	L. Salton	Date:	7/28/05
Copies to:	file	Phone No.:	503-808-3710
Subject:	Water Availability Study Information		
X	*This call was initiated*	Time of Call:	1:30pm
	This call was received	Call Duration:	15 mins.

Notes:

Shannon McDaniel is the Secretary and his name appears on the MOU for the Columbia River Initiative. He was aware of the work we were doing for the USBR. He talked about an Investigative Report that USBR did in 1947 for Foster Creek (Chief Joseph Dam). The copy he had didn't have any kind of publication number on it. I suspect this is already in the library, but will follow up Ed.
He also used to have in his possession a report that the USBR did just after the war. He said it was quite comprehensive, he found it in a used bookstore but has loaned it out and doesn't know where it is.
Finally, he mentioned a report Harza did (sometime around 1985-88) Colville Indian Reservation, Chief Joseph Dam. I'll check to see if this is in the library, if not can search our archives since it's a Harza report, someone must still be around that knows about it......

MWH

TELEPHONE LOG

Persons Contacted:	Garth Gunter	Project Name:	Columbia River Storage Options
Affiliation:	Quincy-Columbia Basin Irrigation District	Project Number:	1004446
MWH Rep.:	L. Salton	Date:	7/28/05
Copies to:	file	Phone No.:	509-787-3591
Subject:	Water Availability Study Information		
X	*This call was initiated*	Time of Call:	2:30pm
	This call was received	Call Duration:	15 mins.

Notes:

Keith Franklin, the Asst. Secretary who signed the MOU for the Columbia River Initiative (CRI) is now retired and I was referred to Garth. He was aware of the CRI work but couldn't think of any additional info to pass along at present. He said he would pass this along to his manager to see if he knew of anything to suggest and that he would see if he could find anything else as well.

PN CENTRAL FILES (as of 7/22/2004)						
Title	Date	Classification	Project	Location	DESCRIPTION	AUTHOR
Brewster Flat Unit Foster Creek Division Definite Plan Report chief joseph	1955		CJP	U4	Definite Plan Report Brewster Flat Unit Chief joseph	Bureau of Reclamation - Boise Regional office
Foster Creek Division Definite Plan Report Chief Joseph General plan Bridgeport Bar Unit	1955		CJP	U4	Definite Plan Report Bridgeport Bar Unit Chief joseph	Bureau of Reclamation - Boise Regional office
FOSTER CREEK DIVISION CHIEF JOSEPH PROJECT Fish and Wildlife	1961	565	CJP	A15	An initial follow up report on the fish and wildlife resources	Interior-Fish and Wildlife
FOSTER CREEK PROJECT COLUMBIA RIVER Fish and Wildlife	1951	565	CJP	A15	Preliminary evaluation report on fish and wildlife resources	Interior-Fish and Wildlife , Region 1

No.	Loc	box	Document	Agen
28.000			**CHIEF JOSEPH DAM PROJECT, WA** includes **Foster Creek Project** and **Greater Wenatchee Project**	
28.204			Chief Joseph Dam Project, WA, *Colville Indian Reservation and Adjacent Areas, Appraisal Report,* July 1979	usbr
28.404		law 09	Chief Joseph Dam, Project, WA, Foster Creek, 79th Congress, 2nd Session, H.D. No. 693, nomonth 1946 • *"Columbia River at Foster Creek, WA, Letter from the Secretary of War ... Dated l 6, 1946, Submitting a Report, together with Accompanying Papers and Illustrations, on a iew of Reports on the Columbia River and Tributaries, Oregon and Washington, for rovement at and in the Vicinity of Foster Creek, Requested by a Resolution of the Committee ivers and Harbors, House of Representatives, Adopted on 24 March 1942* (nomonth 1946) • Transmits ACOE Seattle District Engineer report of August 1945 [see pg. 5]	cong
28.408			Chief Joseph Dam Project, WA, Foster Creek, *Interim Report*, March 1948, • **2/25/04 missing	usbr
28.412			Chief Joseph Dam Project, WA, Foster Creek, *Reconnaissance Report,* November 1948, • **2/25/04 missing	usbr
28.416			Chief Joseph Dam Project, WA, Foster Creek, *Reconnaissance Report,* May 1949, • **2/25/04 missing	usbr
28.420			Chief Joseph Dam Project, WA, Foster Creek, Brewster Flat Unit, *Definite Plan Report, Volume 1, General Plan,* September 1955, Region 1	usbr
28.424			Chief Joseph Dam Project, WA, Foster Creek, Bridgeport Bar Unit, *Definite Plan Report,* October 1955, Region 1	usbr
62.440	G 14 2		Colville Confederated Tribes, WA, *Witness Book, Colville Indian Appraisal Study,* ?August 1979, USBR, • see also Chief Joseph Dam Project, WA, *Colville Indian Reservation and Adjacent as, Appraisal Report,* July 1979	

No.	Loc	box	Document	Agen
		fws 02	Foster Creek Project, WA, *Preliminary Evaluation Report on Fish and Wildlife Resources,* February 1951, FWS Portland [also see **Chief Joseph Dam Project, WA**]	fws
		fws 02	Foster Creek, WA *Chief Joseph Project, WA, Foster Creek Division, An Initial Follow-Up Report on the Fish and Wildlife Resources,* December 1961, FWS Portland	fws

APPENDIX B - DESCRIPTION OF ABBREVIATED TECHNIQUE

INFORMAL BRIEF

Pre-Appraisal Cost Estimating Approach

Columbia River Storage Study

The development of detailed cost estimates was not part of the scope of work for the Columbia River Storage Study (Study) conducted by MWH under Contract No. 03CA10150A for the Bureau of Reclamation. It was part of the scope, however, to develop evaluation criteria for determining if an identified alternative off-stream site should be studied further to include an estimated pre-appraisal level Total Construction Cost parameter. An abbreviated procedure was conceived to estimate this parameter since there was neither time nor money to carry out the activity in detail.

Normal practice in developing cost estimates would be to calculate material quantities based on a level of design of the project features, i.e. conceptual, feasibility or final design. In the absence of any design whatsoever, the notion of using existing cost estimates of similar type projects in the northwest vicinity was explored. A search of existing reports on similar projects revealed two recently studied projects for off-stream storage reservoirs connected to the mainstem of the Columbia River, the Wymer Project and the Black Rock Project both in the Yakima Valley. The Wymer project feasibility cost estimate was completed in 1985 and the Black Rock cost estimates were completed in 2004. The project concepts were similar to the type of projects identified in this Study. They included a dam, reservoir, pumping plant, water conveyance structure and a spillway and/or outlet works facility.

An examination of the cost estimates revealed that considerable detailed information had been developed for both the Wymer and Black Rock projects. Further, the relative sizes of the two projects seemed to encompass the proposed size of most of the alternative sites in this Study. The Wymer reservoir volume was 174,000 acre-feet, the smaller Black Rock alternative was 800,000 acre-feet and the larger Black Rock alternative was 1,300,000 acre-feet. The volume of the 11 dams identified in our Study all fell within this range with the exception of two, Goose Lake and Foster Creek (larger by approximately 50%).

MWH developed a valley profile and proposed dam height for each identified site as part of its determination of potential reservoir storage volume. With this basic information, it was possible to calculate an estimated volume of dam materials based on an assumed dam cross-section. The assumed dam type was a central core, rockfill embankment type dam with a cross-section having a 40 foot wide crest, an upstream slope of 1.75:1.0 and a downstream slope of 1.5:1.0. The average end method was used to calculate an approximate volume of total dam fill material with no consideration of individual material zones.

After careful examination of the prices used for Wymer and Black Rock, the prices used for the central core rockfill Black Rock alternative were selected because they were the most recent and the most detailed. The ratio of embankment fills for a Study site and the larger Black Rock alternative was then calculated. The ratio was multiplied times $117,000,000.00 and entered into the cost spreadsheet for dam structure. The $117,000,000.00 was a rounded amount representative of costs for dam foundation excavation, treatment and grouting for the Black Rock large alternative. Spillway/outlet works estimates were derived by taking a percentage of the dam structure cost, ranging from about 10 to 15% depending on the site. For some of the sites an outlet works would be the primary waterway and for some sites there may also be a spillway if the watershed would generate sufficient runoff to warrant a spillway.

The pumping plant facilities, including all structural, mechanical and electrical equipment were estimated as a lump sum for each project. This was done using detailed field cost estimates prepared in 2004 for a 3,500 cfs and 6,000 cfs pumping facility for Priest Rapids on the Columbia River (1287 ft. head). All-inclusive pumping plant costs were estimated by interpolating the respective site pumping capacities between the two Priest Rapids data points. Reductions were applied to pumping plants in the Study where static heads were significantly less than the two Priest Rapids plants.

The cost of the waterway was initially estimated based on steel pipe. For the combination of head and diameter necessary for the projects, steel pipe would generally not be cost effective and a single pipe would probably be technically infeasible for some sections. Waterway costs were therefore based on tunnel costs from two sources. A recent detailed cost estimate was available for a 15,000-ft long, 12-ft diameter tunnel near Juneau, Alaska which was adjusted to a location in eastern Washington. A second approximate tunnel cost estimate was obtained directly from a major construction company for a range of tunnel sizes. When adjusted to a common tunnel size and location, these two sources resulted in essentially the same tunnel unit cost, which was used for the waterway cost estimate. For any of the Study sites selected for more detailed studies in the future, pipes or canals may be technically more appropriate in place of some or all tunnel sections and the cost estimates will reflect those changes.

As explained clearly in report Section 5.1.5 Pre-Appraisal-Level Cost Estimates, 45% of the direct construction costs were added for mobilization (5%), unlisted items (15%), and contingency (25%). Further, to account for indirect costs, another 20% to 35% inclusive of land acquisition, environmental/permitting, engineering design and construction management was added. The sum of all elements is considered an estimated Total Construction Cost.

The Black Rock estimate was pegged to June 2004. No adjustment for escalation was included. No account was made for project financing such as interest during construction, debt service, financial services, etc., or operational expenses or maintenance costs. The approach described in this brief is also subject to the assumptions and limitations expressed in Sections 5.1.5 and 6.2 of the draft report submitted to the Bureau on October 17, 2005.